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ECONOMICS OF REAL PROPERTY MAINTENANCE DECISIONS IN THE NAVY

Gerald H. Ross, M.P.W., M.S.C.E.

University of Pittsburgh, 1971

This thesis provides interested Navy personnel with a background of the maintenance management programs for real property facilities as exists in the private sector of the economy, including a review of the factors which are weighed by the decision-makers in determining what requirements need to be accomplished. Simultaneously, an effort has been made to discover a good indicator of real property maintenance which might be adaptable to use by the Navy. This investigation of industrial maintenance management offers another yardstick for evaluating or examining the economics of real property maintenance decisions in the Navy.

The Navy presently uses a real property condition indicator called BEMAR (Backlog of Essential Maintenance and Repair) for justifying

requests for shore station funding in the public works area. BEMAR consists of repair projects, each individually estimated at greater than ten thousand dollars, and is expressed as a ratio of the total value of these projects to the current plant value of the Navy's inventory. This indicator is used since no other one is available and thought to be superior. A search is continually being made for a better one.

Another past practice of justifying real property maintenance funding levels and illustrating the inadequacies of appropriations has been the use of quantified data which purported to be industrial standards. Such information, if valid, could provide a comparison for evaluating the Navy's expenditures for real property. On the other hand, unreliable data serves no useful purpose and the use of same should be avoided.

The author interviewed maintenance management personnel in industry, prepared and mailed a comprehensive questionnaire to selected industrial firms, and conducted an extensive search for relevant literature to provide a base for the contents of this thesis. The information gathered from these sources has been integrated to project the story of real property maintenance policies found existing in private industry.

The tremendous amount of variation in maintenance programs was found in industry and this is highlighted. Classifications of work, cost accounting, budgeting procedures, and the general philosophy and policies of different companies were shown to contribute to the dilemma of developing any reliable data as industrial standards.

The upkeep of real property facilities has been seen to be an insignificant part of the total maintenance expenditure in industry with the emphasis on the maintaining of productive units. Importance is attached to facilities directly related to production such as utility systems. Maintenance projects which have an impact on employee morale and productivity also receive high priority. Economic considerations are most important when projects become capital expenditures. In reality smaller projects are not closely scrutinized although maintenance personnel subjectively apply certain economic principles. Real property facilities are also held to an absolute minimum to hold down maintenance expenditures. Another favorite practice is to accept an initial high first cost for construction with subsequent lower annual maintenance costs. Property condition indicators are not widely used in industry with only three being found.

The author concludes that some of the practices used in private business are applicable for Navy use. Navy hierarchy should be provided with all the economic data necessary to make sound decisions. Economics as to timing and future implications should be provided for projects in the Navy as in industry. NAVFAC should determine the costs associated with deferring projects. These costs plus quantifying operational losses and employee turnover must be determined. The Navy, like industry, must reduce facilities to an absolute minimum. High initial costs for construction must be continued until decision-makers are made aware of the consequences of life cycle costs. The Navy should not use so-called industrial averages because they are not reliable. The real property condition indicators found in use are not an improvement to BEMAR.

The author recommends a change in the project forms being used by the Navy to provide the decision-makers with better economic data. NAVFAC should also undertake a study to determine the rate of personnel turnover due to inadequate facilities for living and working. Operational losses should be added to maintenance costs in replacement studies. The Navy should take immediate action to reduce real property inventories to a minimum. It is also recommended that NAVFAC refrain from using industrial standards since they are not reliable.

DESCRIPTORS

Budgeting
Economic Analysis
Industrial Plants
Maintenance
Maintenance Management
Public Works
Real Property

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1.0 INTRODUCTION

1.1 General

The Naval Facilities Engineering Command (abbreviated NAVFAC) has been assigned technical responsibility for Navy Public Works and Public Utilities[1] of the Shore Establishment of the Navy.[(1)*] In carrying out its duties one of the most important functions of NAVFAC is the operation, maintenance, and repair[2] of these shore facilities. The Naval publication Inspection for Maintenance of Public Works and Public Utilities states:

> "The Naval Facilities Engineering Command, under the authority of the Naval Charter and General Order 19, is responsible for the Annual Survey, and exercises technical direction of the alteration, repair, and estimate of funds required for the maintenance of Public Works, Public Utilities and Civil Works[3] in which the Navy has an interest."[(2)]

At the local activity level, the management and control of maintenance and operation of public works and public utilities is a command responsibility. This responsibility is delegated to the Public Works Officer who performs the assigned tasks of management and control through the Public Works Department.[(3)] Within available resources the engineering staffs at all levels endeavor to ensure the best combination of phys-

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*Parenthetical references placed superior to the line of text refer to the bibliography.

[1]Appendix A lists the public works and public utilities which are defined within the naval shore real property inventory.

[2]The term, maintenance, as used in this thesis refers to the recurrent work required to preserve or restore a facility to such condition as it may be effectively utilized for its designated purpose.

[3]Civil Works refers to Navy owned realty operated by private contractor.

ical conditions, service and economy of the Navy's real property facilities.[1] Efficient and economical management is a primary interest. It requires that under maintenance and over maintenance be avoided and that corrective action be taken on identifiable deficiencies in a timely manner before deterioration necessitates major repairs or jeopardizes the safety and welfare or personnel of other property. The planning, forecasting and justifying of an adequate budget in order to accomplish these tasks in an effective and economic manner is of paramount interest to the responsible engineering personnel.

In recent years the real property maintenance management personnel in the Naval Facilities Engineering Command organization have expressed concern over "an inadequate and a declining real property maintenance funding level."(4) A major instrument used by NAVFAC for supporting annual requested funding levels has been the reporting of its Backlog of Essential Maintenance and Repair (abbreviated BEMAR).[2] (5) Other supporting data of annual budget requests for real property maintenance facilities has periodically included information which purported to be standard industrial practices.(6) The first one, BEMAR, has apparently become ineffective. Some decision-makers have apparently lost confidence in the credibility of BEMAR as an indicator of real property condition.(7) It is evident that the Navy must re-establish complete confidence in BEMAR by demonstrating its validity or develop a new acceptable indicator

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[1]Real Property refers to a building, structure, or other real property improvement. See Appendix A.

[2]The Backlog of Essential Maintenance and Repair is comprised of real property major repair projects which are estimated to cost $10,000 or more to accomplish.

if it hopes to achieve the level of funding that it deems necessary to adequately maintain its real property.

A comparison with industry serves as another yardstick for evaluating the Navy real property maintenance requirements. Because of the competitive environment and the profit-making motive in private industry, it is generally accepted that private producers will endeavor to achieve maximum efficiency of its operations in order to maximize profits. Any argument to this point of view is not considered to be within the scope of this thesis; however, it is difficult to imagine that a private market producer would intentionally operate in a wasteful manner. Since incentives for an efficient maintenance management program (as well as other corporate functions) can be assumed to exist in most successful businesses, a comparison with industrial practices provides another potential evaluation of real property maintenance techniques utilized by the Navy.

As mentioned previously, the Navy does periodically use industrial maintenance practices as a tool for analyzing its maintenance activities and budget requests. Appendix B contains two such examples. However, these past examinations of industrial maintenance practices have been cursory. This has been due primarily to a lack of manpower to pursue such a study. Naval Facilities Engineering Command personnel indicate that a series of corporation interviews by a reserve officer was conducted at one time. The interviews were confined to discussing their method of determining maintenance requirements and did not cover such items as backlog and budgeting. The results have subsequently been misplaced and are not available. This appears to be the extent of any investigations of industrial maintenance practices. Therefore, it is

important that this very large and important sector of our economy be explored to determine if techniques of its maintenance management activities are valid for Navy use. It is also necessary that the Navy avoid using invalid information as its use could be embarrassing if incorrect.

1.2 Objectives

The objectives of this thesis are to:

(A) Provide interested Navy personnel with a background of the general philosophy and policies found in private industry maintenance management. This thesis will cover a review of various budgeting and allocation processes for maintenance funding. The policies discussed will provide information regarding the establishment of the proper level of economic maintenance in private industry.

(B) Review some of the economics and irreducible factors in evaluating industrial maintenance requirements.

(C) Discuss various indicators of real property plant condition found in private industry for their comparison with the BEMAR system used by the Navy.

(D) Discuss the applicability of these various industrial maintenance management techniques for use by the Navy.

1.3 Significance of Study

The significance of the study is basically twofold. First, if standard industrial practices are to be used by the Navy as an instrument for comparing or supporting its maintenance management effectiveness and

needs, then any data promulgated should be verified and established as being meaningful and comparable.

Second, the Navy is constantly in search of improvements for its maintenance management program. If private industry possesses any tools which could be adapted to the Navy system with favorable results, then every effort has to be made to discover them. Currently, the Navy uses BEMAR as an indicator of plant condition. This study is significant in that it illustrates the methods employed by private industry to express differences among separate plants.

1.4 Research Methodology

Four methods of gathering information were utilized in the preparation of this thesis. An extensive search of relevant literature available was made at:

(A) all University of Pittsburgh libraries;

(B) the Carnegie Library;

(C) the Carnegie-Mellon University Library;

(D) the Allegheny County Regional Reference Library.

The literature reviewed included: many published books on engineering economy, industrial engineering, and maintenance engineering; publications of professional societies; magazines and technical journals; Navy publications, instructions, and directives; and studies under contract by engineering consultants for the Navy. The Navy literature was obtained from numerous sources by past and present naval personnel attending the University of Pittsburgh.

The second research method employed was the analysis of a comprehensive questionnaire (Appendix C) that was distributed to major private business firms headquartered in the United States. Corporation names and addresses were taken from Poor's Register of Corporations, Directors, and Executives.(8) The decision for selection of the firms was based on the following rationale:[1]

(A) The company product or service necessitated real property facilities similar to those found in the Navy's inventory. Some airline companies were sent questionnaires because their real property inventory requires the maintenance of hangars, administrative, POL[2] facilities, etc. Large petroleum companies were selected for an inventory of waterfront facilities, POL facilities, administrative buildings, roads, streets and parking lots, etc.

(B) The large size of the corporation. This was desirable because of the tremendous plant value of the Navy's real property.[3] Larger companies were considered to be more realistic for accomplishing the purpose of this thesis.

(C) Maintain multi-plant operations in different climatic areas. This factor would provide the same influence experienced by various Navy bases scattered throughout the United States and foreign countries. This factor increases the possibility of discovering if indexes of comparing plant conditions are used in private industry.

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[1]The author made every effort to select firms meeting as many of the first three factors as possible.

[2]POL is an abbreviation used in the military to mean petroleum, oil and lubricants.

[3]The Navy's plant value at the beginning of fiscal year 1970 was 27.8 billion dollars.

(D) Corporate headquarters in Pittsburgh. Some firms were selected because they were headquartered in the Pittsburgh area and could be interviewed as a follow-up to the completion of the questionnaire.

Sixty-one[1] questionnaires were mailed to firms selected on the basis of one or more of the above listed factors. Twenty-one firms returned a completed form. Three other companies elected to provide narrative information describing their maintenance policies. This was a thirty-nine per cent favorable return. Twelve other companies returned letters of apology for not being able to participate. Major reasons given for these negative responses were basically in two categories: i.e., (1) lack of manpower available to complete the detailed questionnaire, and (2) not in accordance with company policy to complete the form.

The questionnaire was devised by the author after analyzing available information in a library developed by the Naval Civil Engineer Corps Officers attending the University of Pittsburgh. Design of the questionnaire was intended to provide general information regarding maintenance management policies and standards used by companies in the private sector of the economy. For the purposes of this thesis the author analyzed the returns and extracted the information that was believed to be meaningful. These various points of interest presented by individual companies will be cited and integrated with data obtained from other sources. When deemed appropriate, a summary of results will also be presented.

A third method of collecting information for this thesis was the use of personal interviews. Ten interviews were conducted with manage-

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[1]Appendix D lists the sixty-one firms.

ment personnel from seven companies located in the Pittsburgh area. These interviews averaged approximately two and one-half hours in length.

The fourth method of thesis research was the author's participation in local chapter meetings of the American Institute of Plant Engineers. This method provided additional information through discussion of maintenance policies with member engineers.

The data collected by these four methods will be integrated and presented in an order that will project the industrial maintenance story in the most meaningful way.

Chapter two, MAINTENANCE PHILOSOPHY AND POLICY, will examine the corporation's establishment of maintenance policies. This chapter will also review the maintenance department and its role in the company's objective. The level of economic maintenance as exists among various industries will be discussed.

Chapter three, ECONOMIC ASPECTS OF INDUSTRIAL MAINTENANCE, will trace the various economic factors included in maintenance decisions of private businesses. Replacements, upgrading, initial designs, deferring repairs, depreciation and taxes will be among the factors discussed. Meaningful examples relevant to economic decision-making will be illustrated. The irreducible factors in maintenance decisions will also be examined.

Chapter four, INDEXES AND INDICATORS OF PLANT CONDITION, will examine the methods used in private business to determine plant condition.

Chapter five will contain the SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS.

1.5 Limitations of Research Methodology

The author recognizes the limitations of the data collection methods used for this thesis. Questionnaires are recognized to provide opportunities for error.[9] Some of the pitfalls seen as major sources of error are: (A) improper interpretation of questions; (B) reluctance to furnish valid information to some of the questions; and (C) lack of interest on the part of respondent.

Another limitation was the unwillingness of most firms to discuss their economic policies because of their competitive position. Some individuals whom the author interviewed acknowledged that there was a limitation to the information they could provide.

A third major constraint was the limited amount of published information available on the maintenance of real property facilities such as buildings, structures, etc., in private industry. Most of the industrial maintenance literature stresses production machinery.

2.0 MAINTENANCE PHILOSOPHY AND POLICY

This chapter will introduce the functions of maintenance engineering in industry, the types of maintenance work, increasing cost trends, maintenance management objectives, and the relationship of maintenance objectives to corporate profits. The economic level of maintenance will be introduced and discussed in relationship to productive and non-productive assets. Deferring maintenance and budgeting processes will also be introduced.

2.1 Functions of Maintenance Engineering in Industry

The scope of the maintenance engineering function in industry is usually quite broad and ordinarily includes most of the following primary and secondary functions:(10)

(A) Primary functions of Maintenance Engineering:

(a) maintenance of existing plant equipment;

(b) maintenance of existing plant buildings and grounds;

(c) equipment inspection and lubrication;

(d) utilities generation and distribution;

(e) alterations to existing equipment and buildings;

(f) new installations of equipment and buildings.

(B) Secondary functions of Maintenance Engineering:

(a) storekeeping;

(b) plant protection including fire protection;

(c) waste disposal;

(d) salvage;

(e) insurance administration;

(f) janitorial services;

(g) property accounting;

(h) pollution and noise abatement;

(i) any other service delegated to maintenance engineering by plant management.

This list represents a good cross-section of the functions found in maintenance engineering; however, it is not typical for all plants. The maintenance department of each plant is organized to fit the needs of the company. It is generally accepted that what may be good for one plant may not be for another.(11) As indicated above, the maintenance department may take on additional functions as assigned to it by management. One local plant engineer indicated that "our maintenance department is a catch-all for whatever jobs top management has and doesn't know where to put."[1]

The purpose of this section has been to introduce the reader to the variety and breadth of the functions which can be found in industry. Discussion of each function is not within the scope of this thesis; however, the difficulty of trying to compare costs or develop averages for real property facilities will be discussed further under 2.7.

[1]The interviewee requested to remain anonymous.

2.2 Types of Maintenance Work

The classifications of maintenance and repair work used in private industry and the definition of each will vary from plant to plant, company to company, etc., depending on management philosophy and policy.(12) In the author's opinion, semantics is a major drawback here. One company uses five categories: routine; repetitive; non-repetitive; estimated; and non-estimated.(13) Another firm uses three: non-repetitive, less than ninety-six hours; non-repetitive, greater than ninety-six hours; and repetitive.(14) Another company divided work into four categories: emergency work; preventive maintenance; routine repair and maintenance; and facility improvement and major maintenance.(15) It is interesting to note that "routine repair and maintenance" under the latter firm includes "relatively small jobs of the non-recurring nature, essential to achieve optimum plant standards of maintenance, are considered routine repair and maintenance." This contrasted with one of the companies interviewed.[1] In this particular case, maintenance was classified as either "ordinary" or "extraordinary" with the line of demarcation being whether it occured at least once per year irrespective of size. (Appendix E is a copy of the company's extraordinary maintenance work for the 1969 budget year.) Although twelve hundred dollars was the smallest project listed as "extraordinary" in that year, their 1971 listing included "clean ventilation ducts, $800". A third category of work for this department is new construction.

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[1] Interviewee requested to remain anonymous.

In general, it is found the companies will differentiate between work categories based on: dollar value of project; man-hours estimated; frequency of work; type of funds (capital or expense) used; and method of determining work requirement. Maintenance Engineering Handbook reports six categories.[16]

(A) Maintenance Inspection. This category includes:

(a) periodic inspections of machines and equipment to ensure safety;

(b) ensuring equipment receives proper attention at specific periods;

(c) examination of items during maintenance operation to determine feasibility of repair.

(B) Preventive Maintenance. This work includes the checking, adjustment, routine replacement, lubrication, and clean-up necessary to make certain that the facility and its equipment are in proper condition and ready for use. This work is predictable and adaptable to accurate planning and scheduling.

(C) Repair. Corrective repair to alleviate unsatisfactory conditions found during preventive-maintenance inspection. Repair is considered the unscheduled work, often of an emergency nature, necessary to correct breakdowns. With an adequate preventive maintenance program, there should be very little of this work.

(D) Overhaul. Overhaul is considered as the planned, scheduled reconditioning of equipment and facilities.

(E) Construction. Includes all construction work within the capabilities of personnel and equipment.

(F) Salvage. The reclamation or disposition of scraps or surplus material.

This following list is one devised by the author after much literature research and a number of interviews.

(A) Routine Maintenance. This is the repetitive job that is performed on a cyclical basis primarily to keep the plant in daily operation. This would include inspection and minor repairs to machines and facility, lubrication of equipment, determining whether major repairs are required, housekeeping, normal grounds care, etc. Preventive maintenance is considered a part of this category. This work would also be scheduled.

(B) Breakdown Maintenance. Work that is a result of equipment or facility failure. In this case routine maintenance work is normally neglected and no work performed on item between breakdowns.

(C) Major Repairs and Alterations. Includes the replacement or repairs to buildings and equipment where the cost of the job is fairly large but the work does not add to the capital asset value of the plant. This is work that can be scheduled.

(D) Special Project and Capital Asset Additions. Non-recurring work that has a frequency of less than one a year. Installation of new equipment that will increase the capital asset value of the plant would be so classified.

2.3 Maintenance Cost Trends in Industry

Industrial maintenance history shows that in earlier days the cost of plant maintenance was considered a minor factor and relatively

unimportant in the over-all company operation.[17] However, in more recent years this situation has changed. The cost of maintaining plant and equipment in adequate condition to United States' businesses was approximately twenty billion dollars in 1969.[18] An appreciation for the magnitude of this growing industrial maintenance cost[1] was emphasized in a paper presented by Mr. K.G. Ward of IBM Corporation at the 1968 National Plant Engineering and Maintenance Show:

> "The annual cost of plant and equipment in this country is $20 billion and it is increasing at the rate of five per cent or one billion dollars a year. This means that maintenance costs in this country are increasing at the rate of $2.7 million each day."[19]

This substantial expenditure has caused management of many corporations to take a closer look at maintenance work and its effect on the profit position of their company.[20]

The combination of growth and high level management interest was also emphasized by Elmo J. Miller:

> "Most companies have seen their maintenance operations grow at an alarming rate in the last 10 or 15 years, and although they do not necessarily want to stop the growth, they at least want to assure themselves that the growth is (1) absolutely required, and (2) tightly controlled - in other words, well managed."[21]

In light of the growth and increased expenditures of maintenance, private industry has endeavored to ensure that plant engineering and maintenance goals are consistent with the objectives of the corporation. As one aerospace executive stated in his paper presented at the nineteenth annual National Plant Engineering and Maintenance Show:

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[1]Primary cause of rising costs due to increasing inventories of automated production machines.

> "We must attempt to be program-oriented rather than facilities-oriented. In other words, we must try to relate facilities projects to business programs."(22)

The following section will discuss maintenance objectives and the profit position of the company.

2.4 Maintenance Objectives and Corporate Profit

In examining and evaluating the effect of a maintenance program on the performance of any company, it is necessary to understand the policy and philosophy of its management with regard to plant facilities. This may differ between industries and even between plants within the same industry. Within its own environment each organization is compelled to establish its own over-all standards for maintenance of facilities to meet its set of objectives. Maintenance management objectives are:(23)

(A) protect the company's capital investment and increase profits;

(B) increase production by minimizing unscheduled breakdowns;

(C) lower manufacturing costs;

(D) protect quality standards;

(E) maintain safety standards, i.e., to prevent injury to life and damage to property.

2.41 Executive Management Interest

The details of how the maintenance department carries out its objectives are not particularly interesting to the corporate executives. Maintenance Engineering Handbook puts this in perspective:

> "It must be remembered that management is primarily concerned in the total cost of maintenance and reliability of equipment rather than man efficiencies, reduction in the cost of supplies, overhead, and other factors which go to make up the maintenance cost."(24)

Top management wants to be provided with the information necessary to allow it to assess maintenance performance in relationship to the corporation profit situation.

2.42 Relationship to Profit

The corporation must satisfy its shareholder's expectation of profits.(25) Shareholders want to receive reasonable compensation for the use of their invested capital. If expectations are not being met, they will invest elsewhere or vote a change in management. This emphasizes the fact that it costs money to use money. If the cost of capital is figured at ten per cent per annum, then the annual charge for the use of ten thousand dollars is one thousand dollars regardless if it is used to purchase new machines, purchase labor, or maintenance and repair. In the final analysis the cost of capital is independent of its intended use, and, therefore an investment in maintenance has to do its part in contributing to the required rate of return.

This compensation, more commonly referred to as return-on-investment or profit, is one of the primary interests of every company executive. However, the cost of maintaining and rearranging company assets plays an important part on what these profits will be.(26) The role played by maintenance in the corporation's profit making motive is described in <u>Maintenance Engineering Handbook:</u>

> "The justification for a maintenance engineering group lies in its use to ensure availability of the machines, buildings, and services needed by other parts of the organization for the performance of their functions at optimum return on investment, whether this investment be in machinery, material, or people. The maintenance function should be considered an integral, important part of the organization, handling one phase of operations. Maintenance is recognized for its contribution to the whole plant operation, not a self-sufficient unit."[27]

The role of maintenance in the private sector of the economy is, then, to contribute to the profit making position of the firm. The first objective of maintenance management is to protect the company's most expensive assets (plant, equipment, production tools, etc.) at a minimum cost over the maximum time it is intended to produce a quality product. To achieve this goal, companies establish their economic level of maintenance which is to be discussed next under 2.5.

2.5 Economic Level of Maintenance

In industry the cost of maintenance can spell the difference between profit and loss.[28] For this reason top management tasks the maintenance department with optimizing these costs. Over-all maintenance cost performance is evaluated in two different lights; i.e., the economic level of maintenance and departmental productivity.[29] Worker efficiency is not within the scope of this thesis, therefore, only the "what should we do" area will be discussed.

2.51 Difficulties in Defining the Proper Level of Maintenance

The proper level of maintenance is a most difficult area to measure and pin down. Maintenance and repair of the physical plant and its equipment is the least understood and most poorly managed segment of modern industry.(30) In a paper presented at the thirteenth annual National Plant Engineering and Maintenance Show, Mr. Frank O. Pierson spoke of the level of maintenance problem: .

> "First, I will assume a situation that rarely exists - that every work order is justified and proper. I have yet to find a maintenance department that doesn't spend money on work that is unnecessary in the light of its basic objective stated, or some of the work should not have been approved. Here you will note I am bringing in one of the facets of maintenance that I said I would not discuss - but you control this facet when you approve or disapprove a work order.
>
> I will also assume - and I believe this to be an even more fallacious assumption - that you know what the proper level of maintenance is to maintain optimum capability in the productive machinery. I have never been in a plant where maintenance had exact knowledge of this."(31)

Plant variations add to the dilemma of establishing a measurement of the proper level of maintenance:

> "What one plant terms satisfactory maintenance another plant might consider unsatisfactory. Periodic reviews of plant operations often indicate that the level of maintenance is either insufficient or in excess of that which is considered optimum for the plant. When attempting to compare some measurement, such as manhours or cost, it is essential that the same level of maintenance exist in computing that basic standard as exists in the study interval. Therefore, whenever the level of maintenance is significantly altered, the standard should be altered. Of all of the variables considered in a labor performance program, the quantitative determination of level of maintenance appears to be most illusive. To my knowledge, no adequate index of level of maintenance exists today."(32)

These opinions were underscored by survey results and interviews with industry personnel.

In response to the questionnaires, thirty-five per cent of the return indicated that facilities were under maintained; sixty-five per cent reported maintenance work adequate; and no firms reported facilities being over maintained.[1] Interviews revealed the basic underlying thought prevailing here, i.e., the maintenance group believes that an adequate job is being done with the money made available but top management does not provide them with sufficient funds to do all that is necessary.

In private industry the maintenance group is at odds with higher levels of management as to what needs to be done. One plant engineer[2] for a local manufacturer complained that "the problem is that everybody is a plant engineer. You only possess expertise when you get fifty miles away from the plant." Many examples were cited to support his opinions regarding inadequate maintenance funding. For example, a wooden block floor had to be replaced because management would not provide funds to replace a badly deteriorated roof. Another example was where a water tower had to receive an expensive sand blasting operation prior to painting because management would not approve the project at an earlier stage.

In contrast to the above, a management representative from an electric product producing company indicated some doubt as to the economics of performing all the project work deemed necessary.

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[1]Questionnaires were returned, for the most part, by maintenance personnel or company vice presidents.

[2]Interviewee requested to remain anonymous.

> "I have projects that my Works Engineer told me ten year ago that they 'had to be done next year' - and they are not done yet. We didn't have the money and had to assign priorities and they were not essential. Of course, you can carry that too far the other way. We have to have an adequate program to keep from sliding backwards. If you listen to engineers, they will engineer you to death. But, of course, they should."(33)

The proper level of maintenance in industry, as seen in this section, is an evasive proposition. It must, however, be in harmony with the over-all objectives of the company, i.e., maintain and increase corporate profit. Operating with a low level of maintenance usually means a larger number of emergency breakdowns and deterioration of plant with resulting production losses and higher repair costs.(34) On the other hand, a very high level of maintenance usually means production downtime is very small but maintenance costs are excessive.(35) Overspending on maintenance is actually reducing company earnings by pyramiding the cost of doing business. False economies may prevail, however, if essential work is deferred purely for additional profit motives.(36) The optimum level of maintenance is that which provides for the maximum production of quality products at the lowest over-all unit cost.(37) In industry this level of maintenance desired consists of two areas; productive units and non-productive assets.[1]

2.52 Maintenance of Productive Units

Corporate management wants no interference with production schedules since unplanned shutdowns usually mean that dollars are spent for

[1]Non-productive assets are usually those facilities which are similar to Navy real property facilities. Buildings, roads, sewers, etc., are included here.

idle production labor plus a reduced utilization of investment and associated fixed costs. As discussed under 2.51, it would be just as wrong to keep things in better condition than the product requires as it would be to under maintain. The matter is strictly one of good economics. Jobs such as the maintenance of the productive equipment are relatively easy to appraise when compared to repairs to non-productive assets. The author will discuss production equipment maintenance in this section and non-production assets under 2:53.

In industrial maintenance two extremes are possible: (A) one is to run the equipment until it fails and then fix it; (B) the other is to try to avoid all failures by following a stringent preventive maintenance program and replace all parts before they fail.[(38)] Most firms find that either extreme is uneconomical and try to strike a favorable balance somewhere in between. The cost of the preventive maintenance program[1] must be less than the cost of unscheduled downtime.[2] [(39)] Figure 1 illustrates this concept.

Establishing the preventive maintenance program for an industrial firm usually entails identification of units that are classified as "critical units".[(40)] Qualification as a critical unit includes:[(41)]

(A) Failure of the unit would endanger health or safety of personnel.

(B) Failure would affect quality of the product.

(C) Failure would stop production.

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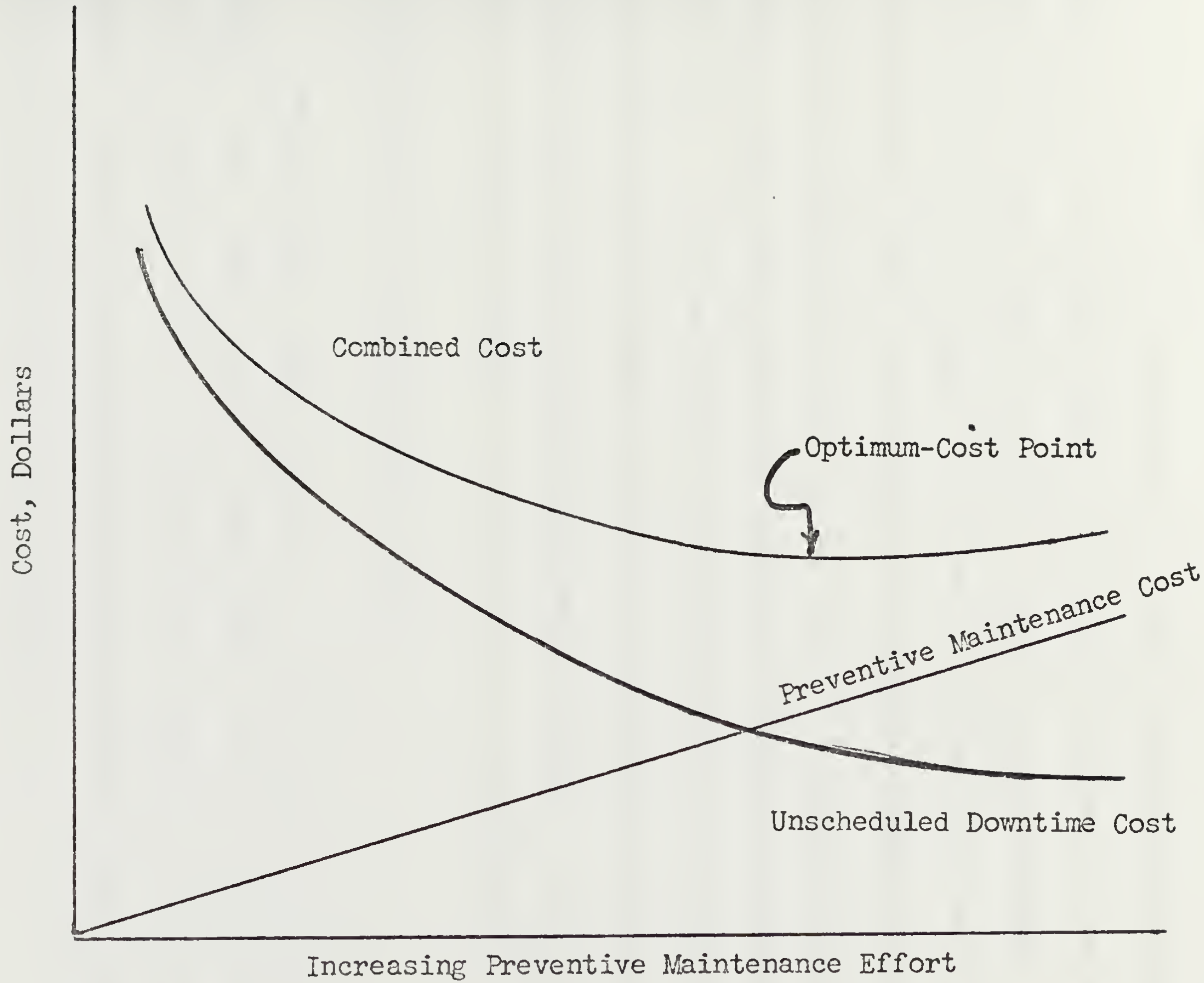
[1]Preventive maintenance costs refer to inspection costs, scheduled repair cost and scheduled production loss.

[2]Unscheduled downtime cost refers to emergency repair cost, production lost time, product spoilage, loss of customers, etc.



OPTIMIZING PREVENTIVE MAINTENANCE COST

FIGURE 1

(D) Capital investment for a unit is high.

If breakdown results in severe damage to the equipment or excessive repair costs or unacceptable loss in production then qualification as critical usually results.

In spite of the advantages of a sound preventive maintenance program, many plant engineers must live with the fact that in some cases it is wiser (more profitable) to allow an item to run to breakdown. In an interview at a local company, the interviewee stated that one of the large plants for which he was responsible had approximately fifteen hundred pieces of production equipment but only two hundred qualified as "critical units" and received any preventive maintenance attention.(42) In this case, company management experienced that breakdown maintenance on the other thirteen hundred units was more economical than employing additional labor for a preventive maintenance program.[1] By analyzing costs, the company determined its optimum level of maintenance.[2]

2.53 Maintenance of Non-Productive Assets

Non-productive assets maintained in industry are the buildings (masonry, roofs, floors, etc.), roads, sewers, etc.(43) These are facilities not directly related to producing the product but are necessary for support. Non-productive facilities are essentially the same as the facilities the Navy classifies as real property.[3]

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[1]The interviewee indicated that a higher degree of preventive maintenance in the firm proved uneconomical.

[2]This was the opinion of the company representative and not the author's.

[3]See Appendix A

2.531 Significance of Real Property Maintenance. Before proceeding with a discussion of the level of maintenance in this area, the author will first attempt to establish the proper frame of mind for the reader. Total maintenance cost will range from three to fifteen per cent of the total manufacturing costs.(44) In turn, this non-productive maintenance cost varies between five and fifteen per cent of the maintenance dollars.[1] (45) Consequently, the cost of maintenance, and particularly the non-productive type, is regarded as a necessary evil by corporate officials.(46) As such they fail to receive a high priority. In a conversation with the Works Manager of a chemical producing firm, he stated, "We spend one hundred-thirty million dollars per year on maintenance of which a small amount, two to three per cent, is for real property. It isn't a big thing - it is a big thing - but in light of other things it is insignificant."(47) It was also indicated that ten to fifteen per cent of the maintenance budget was used for rearrangements, additions, and modifications.

2.532 Company Programs. In general, maintenance of real property facilities is recognized to have no direct effect on production levels or machine operating hours.(48) It is difficult to quantify what a chimney repair or fence repair is to the worth of the product. This creates a different problem than that experienced with maintaining production equipment.[2]

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[1] Maintenance on real property facilities is commonly classified under "general maintenance cost." This is discussed under 2.7.

[2] See 2.52.

The variation between plants reflects different management policies and philosophy. Survey results indicate that most companies try to inspect their real property facilities annually. Semi-annual inspections are also popular. Charles D. Scott indicated this preference in a paper presented at the Nineteenth Annual Plant Engineering and Maintenance Show:

> "The primary purpose of a building is to protect the occupants and the contents from the elements.
>
> If a building is to continually perform the function for which it is designed, it must at all times be maintained in good condition. It is, therefore, well to inspect buildings at least twice a year; once in the late summer before severe winter weather sets in and once in the spring after the long winter months. All defects should be promptly remedied. In this way, a building can be kept serviceable throughout its normal life."(49)

In response to the questionnaire, Holiday Inns reveals that a monthly inspection is company policy. In the "innkeeper" business the real property facilities can also be considered the product. A higher degree of inspection and maintenance in this case is understandable as failure to do so could result in loss of customers and revenue.

The author's interviews with local companies revealed that:

(A) Written company maintenance policies do not normally exist.

(B) Breakdown type maintenance for real property is very common in private industry.

(C) Generally speaking, inspectors are not employed for inspecting most real property facilities.

(D) If inspections are performed there are no inspection manuals or standards (written) to follow. Experience of the person inspecting is the only criteria for determining what to inspect and recording deficiencies.

(E) Manufacturer's recommendations are commonly used for determining amount of maintenance on air conditioning systems, etc.

(F) The level of maintenance performed on real property facilities is primarily a function of the existing business conditions.

2.54 Repair Transaction Concept

One chemical producing company sets its level of maintenance by a method termed "Repair Transaction."(50) The main thrust of this method is to insure that both productive and non-productive assets receive adequate attention. A level of maintenance is established so that plant management can see what it is buying for its repair dollars. For example, with productive assets the dollars of repair cost buy productive on-stream time.[1] The ratio of total production time to total available time indicates to management an on-stream efficiency to relate to maintenance dollars.

The non-productive assets are examined in the following manner. From inspections a program of all foreseeable future (three years) projects are listed. The least critical job to be done in the current budget year compares with the most critical planned for the following year. This provides a visual definition of the minimum acceptable level of maintenance for this year. With this approach, it is possible to decide how much to upgrade or downgrade assets in a given year and to estimate the decision's effect on repair costs. If projects are considered too critical to defer then they are added to the current year's budget.(51)

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[1]On-stream time refers to time productive assets are operating.

2.6 Private Industry and Maintenance Budgeting

This section will introduce budgeting, establish a relationship between maintenance and company budgets, and discuss the establishing of maintenance budget in private industry. The variations among firms will be discussed as well as budget limitations and project deferring.

2.61 Defining Budget

A budget is a financial plan which represents management's best reasonable estimate of expenditures during a definite future period, (usually one year).(52)[1] As such, they are statements of anticipated results based on actual expectations. Budgets can be expressed in terms of man-hours, units of production, or most commonly, as dollars.(53)

2.62 Company Budget

Budgets will vary with firms although in most companies the following budgets are prepared annually:(54)[2]

(A) Sales or volume budgets - by product line;

(B) Production budget;

(C) Expense budgets related to production operations;

(D) Expense budgets for manufacturing services (includes maintenance);

(E) Selling expense budgets;

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[1]Many companies budget for one year in advance but permit adjustments to be made semi-annually, quarterly, or in some cases, monthly.

[2]The author intends only to illustrate a common method of developing corporate budget and not to discuss to constituents of each budget listed.

(F) General and administrative expense budgets;

(G) Engineering expense budgets;

(H) Capital expenditure budgets;

(I) Cash planning budget.

Budgets from each unit are reviewed at each of the levels of administrative control until they reach division[1] or corporate management. Here the profit is set as to what return on investment is desired. The proposed budgets are compared to expected revenue to determine if the rate of return is being attained. If profits are too low administrators are requested to make specific dollar reductions to their budgets.(55)

Maintenance budgets are established in harmony with these company objectives. Common approaches to developing the maintenance budget is discussed next.

2.63 Establishing Maintenance Budgets

In the private sector of the economy the maintenance budget must be sensitive to the variations in the business conditions. As business fluctuates up or down, operating budgets of the company must take account of the changes.(56) A certain amount of maintenance must continue at a fairly high rate, even at lower production levels, in order to keep the plant in a condition necessary to meet demands.(57) At the fourteenth Annual Plant Engineering and Maintenance Show, Albert Chapman addressed the problem of maintaining an optimum operating condition as related to the budget:

[1]Each division commonly operates as an individual profit center.

"The maintenance budget must be so developed that it is a forecast of all expenditures required to keep the plant in optimum operating condition, at a pre-selected physical level. This means, first, that the production machinery and equipment must be maintained in a condition that permits a quality product to be produced with not more than an anticipated amount of interference due to machine or equipment failure; and, second, that the building and its facilities, including the plant grounds, must be kept in such a condition that production is not affected adversely because of any defects, that health and safety of personnel are provided for, and that good housekeeping practices and good public relations are observed."(58)

In industry two budget categories are normally used by maintenance, i.e., those related to production machinery and those forecasting real property facility repair needs.(59) Since the maintenance of the real property category is the primary interest of this thesis, the former will not be discussed per se.

In developing requirements, the maintenance budget is commonly segregated into project and non-project work.(60) Some firms may classify these as ordinary and extraordinary[1] or recurring and non-recurring. The terms used are purely a matter of preference. Basically the non-project work is the normal, routine day to day work that forces do frequently to keep the plant running. This usually includes work up to a certain dollar volume, for example, up to one thousand dollars. The non-recurring work (expense project work) is a list of projects that each plant engineer believes should be accomplished during the year to preserve the plant worth and insure the production of a quality product. These are in excess of the established dollar amount. Typical work in the real property area might include: painting of a building; sealing of roads and parking

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[1]See 2.2

lots; roof repairs; reconditioning of heating, ventilating, and refrigeration equipment.[1]

Under normal conditions, the non-project work is usually fully funded. Project work, on the other hand, usually depends on the scope of the job, i.e., the dollar value. As an example, one division of an automobile manufacturing firm has set up a policy of determining how much it can authorize for project work after its profit forecast and prior to preparation of its capital budget. These projects are divided into two authorization levels: (A) project work over five thousand dollars, and (B) project work under five thousand dollars. Each plant submits to division management a list of projects in excess of five thousand dollars while those less than that amount are lumped together and shown as a total. The former are reviewed and approved at division headquarters based on individual merits while for the latter category funding is based primarily on historical requirements.(62)

2.631 Variations. Variations in developing maintenance budgets in private business is common place, varying even among plants of the same corporate division.

> "Our framework for developing budgets is broad and permits each of our divisions some leeway in the methods it can prescribe for its plants. There are even differences in method of budget preparation by plants within a division. This is permissible provided the basic company-established ground rules are observed. Since each of our plants operates as an individual profit center, a plant manager has reasonable leeway to maintain his plant at the standard he desires. As a result, even with the same division, different plants may have different levels of maintenance, yet

[1]See Appendix E

each will have observed the established rules. Budget preparation procedures can be that flexible."(62)

During an interview the author discussed a slightly different system with a local manufacturing firm representative.(63) In this situation the real property facilities work was performed by a centralized "service department." Under this procedure, each division turns in a profit analysis plan showing what they are planning to make as profit. This is predicated on how much maintenance and repair work they want to be billed for during that budget period. The amount of maintenance work is the total of what these individual divisions think they can afford.

A plant engineer[1] at another location indicated the maintenance budget was the same every year, adjusted for plant facilities added or deleted. Company policy in this case was to repair or replace a certain amount of the most deteriorated components within the inventory each year. An inspection was made to determine which areas of each type work would be accomplished.

Since prices are rising annually this individual thought that the maintenance departments increase in productivity was about equal to the rate of inflation.

Another variation, reported by firms responding to the questionnaire, was the local level approval of major repair projects. The range of those reporting dollar values spread from one thousand to fifty thousand dollars.

[1]Interviewee requested to remain anonymous.

2.632 Budgeting Limitations. Previous discussion has shown that the amount of maintenance and repair work which can be accomplished is dependent upon the profit position of the company. In response to the questionnaire, companies indicated that they would defer maintenance even though it would result in accelerated deterioration.[1] Most of the reasons were because of poor profit positions. Phasing out of the facility and work not affecting production were given as two other reasons.

2.633 Deferral of Project Work. A company that is struggling to stay in the black for a financial period (fiscal year) will be tempted to neglect maintenance.(64) Survey results indicate that appearance items, painting, parking lots, roads, roofing, general housing, and grounds care are the most desirable things to defer during periods of tight purse strings. The economic aspects of deferring will be discussed in Chapter Three.

The relationship between what is accomplished during a fiscal year appears to be a function of profit as indicated in the following quote from an interview with a local company representative:

> "We have periods of good profit and periods of not-so-good profits. Obviously, when profit patterns for the year do not look healthy we cut back the maintenance program to less than what it should be on the average. When it looks like we're going to have a good year we jack it up. We spend more money on the average."(65)

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[1] Five companies indicated they would not defer such maintenance work.

In further discussion with another member of the firm it was stated:

> "When money is not available you do things that you know isn't exactly the right thing to do. We did that for a number of years in the fifties. When money later became a little more plentiful we went into a major rehabilitation program - in fact, we are still working on it. I'm sure that it has cost us plenty of extra money in inflation, but there was nothing we could do. We probably would have gone on like this for another few years, however, the money situation got better, buildings got better, and we got a new general manager. Looks like another ten years under our current program - in the meantime maybe business will get bad again and we will be forced to go back to deferring repairs again."(66)

2.634 Lack of Maintenance Standards. None of the companies interviewed by the author have any type of maintenance manuals or standards for inspecting real property facilities. Repair projects are determined by inspections made by the Plant Engineer or one of his subordinates. The depth and results of the inspections are based on the experience of the inspector. Full-time inspectors are not employed for this type of work.

The balance of the repair work input comes from the production people who report deficiencies or work they would like accomplished.

2.7 Comparing Real Property Facilities in Industry

Ideally, in any situation where someone is trying to look at the same items in two differeint organizations, these items will be the same. The comparison will not be that of "oranges and apples." Unfortunately this is not true when examining real property facilities among industries.

Such facilities most often come under the categories "Buildings and Grounds" or "Land and Buildings". The variation in industry is indicated in Maintenance Engineering Handbook.

> "The repairs to buildings and to the external property of a plant, such as roads, tracks, sewers, and water systems, are generally assigned to the maintenance engineering group. There are, however, many other ramifications of the maintenance of buildings and grounds for which the responsibility varies considerably in different plants. Such items as janitor service, including window washing, floor washing, and general cleaning, often are separated and handled by an employee service group. Frequently road maintenance, including snow removal, is a function of a material-handling group. A plant having extensive office facilities and a major building-maintenance program may divorce all building maintenance from the maintenance engineering group. In some plants (such as an explosives plant) where a large number of buildings are located over a considerable area, the care and maintenance of this extremely large acreage of land warrants a special organization."(67)

Such variation makes it difficult to compare important items like maintenance costs among different companies. For example, one company may exclude certain facilities from its maintenance costs that another company includes, as seen above. Some firms may put business-machines under facilities maintenance while others will not.(68) In comparing costs between different organizations, the comparison must contain only like items if any valid conclusions are to be made. Since each company is free to establish its own system and organization, the number of variations are numerous but some similarity does exist. Companies commonly follow a preferred maintenance-cost plan which is shown in Maintenance Engineering Handbook.(69)

(A) Direct costs are those incurred in the maintenance of operating equipment and auxiliaries. They, therefore, have some relation to production schedules and are proportional as such to some extent.

(B) Indirect maintenance costs cover:

(a) rearrangements when improvements are indicated, whether in process or better handling;

(b) replacements when redesign, different materials of construction, etc., are involved;

(c) new work when not capitalized;

(d) service to operations or other items affecting the maintenance department over which it has little or no control.

(C) General maintenance costs include those for buildings, roads, facilities, air conditioning, etc. - in fact, any maintenance that does not directly affect process operations.

While the ratio of these maintenance costs are known to vary, they are approximately: 70 to 75 per cent for direct costs; 15 to 35 per cent for indirect; and 5 to 15 per cent for general.[70]

The greatest variation comes under the indirect category where "rearrangements" are placed. If a company places this work (or parts of it) under general maintenance costs, it can be quite distorted for comparison purposes.

2.8 Summary

The scope of the maintenance engineering function in industry and the basic types of maintenance and repair work were introduced. The most noticeable aspect of maintenance engineering in industry is its variation between companies and even among plants within the same company. Areas of difference include terminology, classification of work and costs, methods

of budgeting, etc. It was shown for instance that methods of categorizing work varied according to dollar values, man-hour ranges, and type of funds used. The author found the work performed could generally be classified as: breakdown maintenance; routine maintenance; major repairs; and special projects and capital budget projects.

The increasing dollar volume of maintenance expenditures in recent years was observed. Most of the growth has been due to automated production machinery and not real property facilities. Care of real property assets was shown to be a very small part, between five and fifteen per cent, of the total maintenance program. The range of maintenance expenditures as a percentage of the total company budget was shown to run between three and fifteen per cent. This makes real property facilities an insignificant item when compared to other areas of the company investments.

Maintenance management objectives were given as: (A) protect the company's capital investment and increase profits; (B) increase production by minimizing unscheduled breakdowns; (C) lower manufacturing costs; (D) protect quality standards; and (E) maintain safety standards for preventing injury to personnel and damage to other properties. The maintenance objectives were observed to conform with those of the company, i.e., the profit making motive. Management's responsibility was seen as taking care of the company investment while avoiding over maintaining and under maintaining, in order to make its maximum contribution to the long-term profitability of the business.

The concept of economic level of maintenance was introduced. Problems of defining and knowing the optimum level were presented. Varia-

tions in products and management philosophy and policies are major roadblocks in being able to quantify or qualify the proper level of maintenance. A difference of opinion exists between what the engineer sees as the proper level and what top management thinks it should be. The fact remains that the economical level of maintenance appears to be a difficult thing to define in industry.

Care of industrial assets was seen to be divided into two main categories, productive and non-productive. The productive units were more receptive to measuring a level of economic maintenance than were the non-productive. This was accomplished by finding the proper balance between preventive maintenance measures and breakdown costs. It is attained by stopping just short of a point where any additional expenditure for preventive maintenance would not be recovered through the benefits gained from less unscheduled downtime.

It was brought out that it is uneconomical to perform preventive maintenance on all industrial assets. Management identifies its "critical" units for which it is economical to perform preventive maintenance and the remaining assets are taken care of on a breakdown basis.

Non-productive assets, consisting mainly of the facilities identified for this thesis as being real property, were seen to be indirectly related to production and, therefore, not overly stressed. This varies between companies and even between plants. One large hotel-restaurant chain stresses maintenance of real property facilities since they are also their product. The research indicated that, in general, maintenance of real property did not possess a high degree of interest. Most of the maintenance interest was placed on the productive units. Written poli-

cies and standards were practically non-existant and most of the real property assets were taken care of on a breakdown basis.

Company and maintenance budgeting was introduced. It was seen that maintenance budgets are set in harmony with the main company objectives and its function and contribution to those objectives.

Methods of budgeting by different firms were introduced. In general it was seen that maintenance budgets are established in order that the necessary recurring (non-project, ordinary, etc.) work is accomplished. The maintenance department also has non-recurring (project, extraordinary) work and tries to accomplish as much of this work as possible. The amount of work done was shown to be a function of the company's economic conditions. In times when sales forecasts are good, the company will normally do more of this type of work. When business conditions are bad, work will be deferred. If the profit picture is very bleak, this deferral may include projects which will be larger and more expensive to accomplish at a later date. Under such conditions, management tries to defer projects which will have the smallest financial impact if accomplished later.

The dilemma of trying to compare maintenance expenditures was explained. The differences in management philosophies and policies, in defining work categories, in cost accounting, etc., makes it virtually impossible to compare maintenance costs between organizations and, in some cases, between plants of the same company.

3.0 ECONOMIC ASPECTS OF INDUSTRIAL MAINTENANCE

3.1 General

As discussed in the preceding chapter, maintenance budgets are established in harmony with the company's objective of making a profit. In theory a private enterprise allocates resources among its various users in such a manner that it will achieve the greatest economic efficiency in producing its product.[71] As suggested by the marginal utility theory these maximum returns are obtained only if expenditures are distributed among different users in such a way that the last dollar spent for each yields the same return. For example, management will allocate resources to the maintenance department so that the last dollar expended on this type of work will serve as valuable as the last dollar spent on marketing, production, etc. Management has to analyze conditions and determine whether a part of the money allocated to marketing would yield greater returns if it were transferred to another department like maintenance. If greater benefits to the company would result, the transfer would be made.

The above allocation process is necessary in business because most companies have some definite sum of money available for investment purposes.[72] The minimum acceptable return to justify any increment of investment must certainly be as high as the company expects to earn on its other block of investments.

In industry, the proposed investments in maintenance are unattractive unless it seems likely that they will be recovered along with at least a minimum attractive rate of return.[73] By selecting a minimum

rate of return a company is in a position to examine how to best use its limited resources.

Under the above concept, it is evident that every decision made on whether or not to spend dollars on maintenance becomes an economic decision for the business. Each of these decisions requires an identification of alternatives; an evaluation of each; and a choice among them.(74) In private business many popular methods of evaluating expenditure proposals are used.(75)

(A) Intuitive method. This is probably the most common one used. Decisions are based on hunches.

(B) Squeaky wheel method.

(C) Necessity method. This is waiting until replacement is the only answer.

(D) Payout method. This method is used to indicate how many years of annual savings will be required to pay back the initial investment. It has the disadvantage under normal use to neglect time rate of money.

(E) Annual cost method.

(F) Present worth method.

(G) Rate of return method.

The last three are generally accepted as the best methods and the ones used by most well managed companies.(76) The author's opinion (based on survey returns and interviews) is that most of the real property maintenance decisions in industry are made by one or a combination of the first four methods. An exception to this is the larger projects which must be approved as capital expenditures.

3.2 Capital Expenditures

Some major repairs and some improvement projects require funding from a capital expenditure budget.[1] Capital expenditures will now be discussed plus the author will introduce a project "Appropriation Request" form[2] used by a local firm for submitting project proposals to management.

Improvements and betterments are defined as alterations, modernizations, or structural changes to a facility which results in a better piece of property from the standpoint of increased durability, productivity, or efficiency.(77)

Repairs of a major type which are a substitution in kind of a facility or a major part of a facility is a replacement.(78) If replacements extend the useful life of a facility federal regulations usually will not permit the cost to be expensed to that year.(79) Replacements of this nature are classified as capital expenditures and must be amortized over its expected service life. The determination of whether to expense a repair project or charge it as a capital expenditure is usually governed by the company's accounting procedures and the government.[3] Companies have considerable latitude to interpret federal regulations within their own accounting procedures and policies.(80) The following items are usually considered in these determinations:(81)

(A) Size of the work involved (quality of weight, area, volume, or length).

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[1]See 2.62

[2]Identification of the company has been removed at the request of the donator.

[3]The Internal Revenue Service represents the government's interest.

(B) Number of units.

(C) Cost of work performed.

(D) Whether the depreciation is based upon the retirement of the property involved.

3.21 Project Procedure

The starting point of a capital expenditure program is a survey of its "needs."(82) These needs are usually an aggregate of departmental projects which are considered good corporate investments for increasing profits either through cost reduction or profit expanding. Replacement of existing facilities which will no longer function or improvements of existing facilities to circumvent competition are two types of cost reduction (profit-maintaining) projects.(83) A new plant is an example of a profit-adding item.

Companies usually have a limited supply of money available for capital investments and must establish some type of rationing process. The popular method is to construct a "ladder" or "demand schedule" for capital based on prospective rate of return. A simple illustration of such a schedule is:(84)

Prospective Rate of Return	Volume of Proposed Investments	Cumulative Demand
Over 100%	2	2
50-100%	38	40
25- 50%	200	240
15- 25%	1200	1440
5- 15%	3400	4840

Depending on the financial conditions of the company the available capital will be invested in the projects offering the best profitability yield according to the schedule. All of the ramifications of capital

expenditure budgeting are not within the scope of this thesis. The author has merely attempted to illustrate a principle applied in business, i.e., funding the projects which offer the greatest return on investment.

Some aspects of capital budgeting are worth mentioning here. One is that profitability standards might be set differently for various categories of investment because of risk involved.(85) The timing of projects is also important, accordingly, projects are analyzed regarding their postponability, i.e., how long the project can be put off.(86)

3.22 Project Submittals

During an interview the author obtained the form used by one company for requesting project approval and funding. Some of the information required by management will now be presented.[1]

The "Appropriation Request" is a three page form.[2] The first page provides for an identification of project and actions proposed to be taken. The submission must include the anticipated return on investment for two separate cases; one with a terminal value[3] cranked in, and the other excluding it. The effect of deferring the project over a three year period is described. Management is thereby given a visual picture of the postponability of the project. The lower half of the first page has a space for the project approval at the various corporate levels. The size of the project dictates what level of approval is required. Projects over one million dollars require the approval of the board of

[1]The author limits discussion to only those items which are considered relevant to economics and engineering.

[2]See Appendix F

[3]Terminal value refers to salvage value.

directors. The corporation president can approve between one-hundred thousand to a million dollars. The vice presidents may approve projects from fifty to one-hundred thousand dollars. The general manager at the plant has authority up to fifty thousand dollars.

The second page provides an economic comparison of accomplishing the proposed project or rejecting it. Another requirement of the form is a description of disposing of old facilities. Retention must be fully justified. A company goal is to keep facilities to a minimum.

The last sheet requires a statement of the principle alternatives. According to the interviewee, company policy mandates that four alternatives be listed. The economics of each alternate solution are provided based on the discounted cash flow method. Personnel effects are cited, as well as the uncertainties of the project.

Each project proposal has a two year limitation without an extension of time. This means that if a project is not undertaken within two years the approval authority is withdrawn.

3.3 Replacement vs. Repair

The reasons for retiring property, the effect of maintenance on replacement decisions, and economic studies of replacements will be discussed below.

3.31 Property Considered for Retirement

Conditions which lead to the retirement[1] of property include:(87)

[1]Property may be retired by removal physically or by being left in tact but unused.

(A) Physical condition.

(a) accidents (explosions, structural failures, etc.);

(b) catastrophes (fires, earthquakes, etc.);

(c) deterioration from time; This is physical decrepitude which develops and increases during service in spite of maintenance and repair expenditures.

(d) wear and tear from use.

(B) Functional situations. Industrial property is functionally inefficient whenever its services could be rendered more economically by other facilities of the same or different design.

(a) inadequacy or insufficient capacity;

(b) obsolescence; This is usually caused by development of improvements.

(C) Property which is wholly satisfactory but business changes makes it expendable.

(a) termination of the need;

(b) abandonment of the entire enterprise;

(c) requirement of public authority.

Retirements are of utmost importance in industry in that they signify a management decision to end the service usefulness of property. The aim of management is to retire property at the end of its economical service life, i.e., when it is more profitable for the firm to use another property or, at least, no longer profitable to use that particular asset.(88)

3.32 Maintenance Cost Increases with Age of Facilities

No amount of wise expenditure for maintenance can accomplish more than insure that the retirement of a facility is slightly postponed. Structures, buildings, and other properties ultimately wear out, corrode, and decay as a result of age and use.[89] Maintenance costs fluctuate but tend to increase with age.[90] In industry increasing costs for maintenance and repair combined with other costs usually trigger a replacement study.

3.33 The Economic Analyses

Replacement studies may be made for an entire facility (such as a warehouse) or for a part of it (such as a roof). If repairs are numerous and costly, the dollar cost of all the repairs must be weighed against the cost of a new facility. In industry, management knows that assets which are physically as good as new are not necessarily as valuable as when they were new. They may have higher operation and maintenance costs; they will nearly always have shorter life expectancy; service conditions may have changed; and they may be overall more expensive than some alternate. One of the important aspects of an engineer's job is to determine alternatives and the cheapest solution for the company.

In making an economic analysis of a replacement proposal for private industry, the engineer must consider a number of factors.

(A) The resale (market value or salvage value) of the property if replaced with new;

(B) Estimated outlays for taxes;

(C) The life of the facilities;

(D) Depreciation in each case;

(E) Initial cost of new facility;

(F) Cost of operation;

(G) Cost of maintenance;

(H) Cost of interference with production.

All of these factors have to be considered in a replacement study for capital expenditure projects. If the replacement is an expensed repair project then depreciation and taxes[1] are not considered.

In making economic studies of this type the annual cost method is frequently used because people are more familiar with the concepts of annual cost than with the concepts of present worth.(91)

Most repair projects are expensed and do not receive the scrutinous review of capital expenditures. Interviewees indicated that economic calculations for expensed maintenance work are not accomplished except, perhaps, subconsciously. This implies a principle of minimizing costs even though the approach appears to be subjectively applied. The principle is illustrated in this hypothetical problem. Consider a wooden utility pole which is eleven years old and inspection reveals has a deteriorated base, therefore, requiring replacement. An alternative to replacement is to place a new butt in the ground to which the old pole will be strapped. The new pole installed with cost $100 and is expected to last twelve years. The alternate plan of using a butt will extend the present pole life for five years. The cost of the butt installed is $30.

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[1] See 3.7

The salvage value for the old pole now is \$5 and zero at the end of five years. The new pole also has zero salvage value at the end of its useful life. The company uses ten per cent interest in calculating repair problems. The solution can be determined by calculating annual cost of capital recovery.[1] (92)

Capital Recovery (CR) (P-L) (A/P,i,n) + L i

where P = first cost or net realized value

L = salvage value at terminal life

(A/P,i,n) = capital recovery factor[2] for interest, i, and time, n.

For installing new pole, the annual cost is

CR = \$100 (.14676) + 0 x 0.10

CR = \$14.68

For installing butt, the annual cost is

CR = (\$30 + 5) (.2638) + 0 x 0.10

CR = \$9.23

Although the example problem is simple, it does exhibit that alternatives are available with one being cheaper. Solution based purely on judgment may not provide the same answer.

3.4 Life Cycle Concept

In some industries the nature of the products produced cause a cyclic obsolescence of facilities. According to one interviewee[3] this is

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[1] Derivation of the formula is not within the scope of this thesis.
[2] See Appendix G for ten per cent compound interest factors.
[3] The interviewee requested to remain anonymous.

the situation in the chemical producing industry. Facilities are designed and maintained to last approximately six to seven years at which time new facilities will be constructed.

All firms are not able to predict obsolescence as exactly as above. This may result in abandoning facilities at substantial financial sacrifice in terms of investment, in order to benefit from lower operating and overall costs.

An example of the life cycle concept being put to good use is where one company constructed a building for conducting experiments which were to run one year.[93] The building was maintained on that basis and practically fell apart as the experiments were concluded in one year. The low level of maintenance in this case was economically sound.

3.5 Economics of Deferring Maintenance

Deferred maintenance is defined as the maintenance work which has been postponed beyond the date when it should have been performed and which still remains to be funded and accomplished.[94] It is also considered to be one of the most important practical problems occupying the attention of maintenance management today.[95] The amount of maintenance and repair work accomplished during a budget year is governed by the economic conditions of the company. Accordingly, the work for which there are no funds must be deferred.

Private businesses faced with the problem of repair and maintenance cost requirements exceeding funds available will endeavor to accomplish whatever work provides the greatest economic advantage to the company. This means performing the jobs that are essential for production.

Deficiencies that are genuine safety hazards are also essential projects and are not considered for deferral.

After the essential projects, i.e., those adversely affecting production and safety, are scheduled for accomplishment, maintenance management attempts to accomplish the jobs which will benefit the company the most. Once deterioration and causes have been identified a decision among certain alternatives are available to management which includes:(96)

(A) do nothing and permit deterioration to continue;

(B) take measures to preserve the facility in its present condition;

(C) correct or strengthen the deficiency;

(D) replace or abandon the facility.

These alternatives become the basis for an economic decision. If a facility is in a condition whereby failure of less critical components would not result in serious damage, the repairs might possibly be deferred with some financial advantages.(97)

Survey answers indicate that painting, roads, parking lots, grounds, and housekeeping are among the most popular items to defer when funds are tight. Answers to the questionnaire and comments of interviewees suggest that in most cases the decision to defer is based on judgment and that a cost of deferral is not calculated. Some firms indicated that deferral decisions in their company were determined by one of the following:

(A) Extra cost of performing work compared to cost of borrowing money plus temporary repairs;

(B) Cost of repairs required vs. revenue capability of the repaired facility;

(C) Cost of repairs versus replacement;

(D) Economic payback;

(E) Cost penalties of deferral.

The above viewpoints imply that industry looks at the relative economics of doing the work now or deferring until a later date. None of the firms provided their formula for calculating deferral but the payback concept suggests the "break-even point" approach of Sidney Johnson.(98) This is calculated by using the compound interest formula:

$$A = P\,(1+i)^n$$

where A is the cost whose return is to be realized, i.e., the cost of temporary repair plus cost of later repair; P is the amount of deferred expenditure, i.e., the cost of repair now less the cost of temporary repair; i is the interest rate used by the company;[1] and n is the number of years that the repair must be deferred to return the value of the increased work. The equation is solved for n and if the temporary repair will defer the major repair longer than this period, it is considered economically desirable to repair later.(99) In the author's opinion, in-depth analysis of deferring maintenance work, such as that above, is uncommon in industry. Most decisions of maintenance deferral are made by hunches and value judgment. Exceptions are when major repair projects are extremely large and must be funded as a capital expenditure.

[1] Survey results indicate that a ten per cent interest figure is popular in repair project evaluations.

3.6 Lower Preventive Maintenance Levels

An apparent industrial approach to real property maintenance is to have less annual burden expense (inspection and preventive maintenance) and higher renovation or replacement costs as illustrated in the following example.

Maintenance of a pump to keep it in excellent working order is \$225 per year indefinitely.[1] By reducing maintenance costs to \$100 annually, it is planned to replace the pump at the end of ten years at a cost of \$1,000. Stating it another way, the company plans to save \$125 per year in maintenance money and make a replacement in ten years as an alternative. With the reduced maintenance expenditure the firm will invest elsewhere. Using ten per cent interest as indicated by some companies[2] the solution would be as follows:

Using the formulas available in most engineering economic books the future worth of \$125 is found to be \$1,992.[3]

$$F = A\ (F/A,\ i,\ n)$$

$$F = \$125\ (15.937)$$

$$F = \$1,992$$

The calculation demonstrates that in this case it is more economical to perform a lower level of maintenance. In a company where money is valued at ten per cent the maintenance cost would have to be kept below sixty-three dollars.

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[1]Indefinitely is used here to indicate a number of years in the future.

[2]From questionnaire results.

[3]See Appendix G for ten per cent compound interest factors.

$$A = F\ (A/F,\ i,\ n)$$

$$A = \$62.75$$

3.7 Tax Considerations

United States corporations have to pay federal and, in some cases, state income taxes.(100) These taxes may bear some weight in making industrial maintenance decisions. In engineering economy studies where taxes are included, the rate is usually figured at fifty per cent.(101)

As mentioned earlier, maintenance expenditures are frequently curtailed during lean years to enhance the profit picture of the company. Conversely, during more prosperous times, many firms are encouraged to spend more money on repair projects because the government will collect one-half of the profits in taxes.(102) Figure 2 will help to illustrate this point. It is observed that for every additional dollar spent on maintenance the profit after taxes is reduced by only fifty cents. During good economic periods many companies will do additional maintenance jobs in order to obtain the full dollar's value instead of paying half of it in taxes.

Property taxes are not usually considered in maintenance decisions.(103)

3.8 Upgrading Facilities Through Maintenance

Upgrading of facilities is usually accomplished by the use of new and better materials than those being replaced. Upgrading can provide

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[1]Corporation taxes are a form of income tax.

EFFECT OF INCOME TAXES ON EXPENSED MAINTENANCE WORK

	Before Expenditure of Additional $1 for Maint.
Sales for Year	$100.00
Expenses for year	80.00
Profit before income taxes	20.00
Taxes at 50%	10.00
Profit after taxes	$ 10.00

	After Expenditure of Additional $1 for Maint.
Sales for year	$100.00
Expenses for year	81.00
Profit before income taxes	19.00
Taxes at 50%	9.50
Profit after taxes	9.50

FIGURE 2

economic advantages for the company which actively pursues the task of finding and using better materials. The key to a good program is the identification of the cause of deterioration and follow up repairs which eliminate that cause.(104) For example, a large steel plant set up a program for investigation of all material failures and elimination of causes, and, thereby reduced frequency of failures, cut maintenance costs, and improved safety for employees.(105)

During an interview at one local plant it was explained that considerable effort had been exerted in this area.(106) The company now has an active program of improving its future maintenance cost picture by upgrading with better materials. In recent years the program has included such things as: (A) replacing all wooden framed windows with aluminum; (B) reroofing factory building with a new maintenance free[1] type made of aluminum; and (C) installing new gutters made of stainless steel. The last item was felt to be justified because the corrosion atmosphere where the plant was located required frequent replacement of guttering made of other materials.

3.9 Initial Design Considerations

A common economic decision in industry is whether to make a high capital investment in order to reduce annual maintenance expenditures.(107) Persons interviewed in industry were most critical of increasing labor and material cost for maintenance. In most of the firms it was their

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[1]The author is expressing the opinion of the interviewee.

current policy to design facilities with a higher first cost and subsequent lower maintenance costs. Justification for this policy was premised on the present inflation rate of the building trade industry. These sentiments are reflected in the following quote taken from Maintenance Engineering Handbook:

> "Rising costs of factory labor have had marked effect on building design, particularly among companies which have made careful studies of their operating costs. In the days prior to World War II, it was not uncommon for companies to follow a policy of saving money on building costs with the advance knowledge that maintenance charges would be relatively high. Depreciation schedules were such and maintenance labor costs were sufficiently low for it to be more economical in terms of net monies expended to maintain a plant year after year than it would have been to construct it at the outset in such a way that it would require a minimum of maintenance. Mainly because of increased cost of labor, this is no longer the case. Even though building costs are higher, it is still more economical to carry indebtedness on a well-constructed plant than it would to pay out for maintenance of a cheapened plant facility."(108)

Another related problem expressed during most interviews was the incorporation of poor maintenance features in designing new facilities. Because of this problem many companies have added a representative from the maintenance engineering group to sit in as a member on each facility planning committee. This gives maintenance an opportunity to suggest deletions and additions to new designs so that future maintenance costs are minimized. Many companies have included the requirement that maintenance management sign final plans and specifications as being "satisfactory to."

3.10 Irreducibles

An "irreducible" element is one which cannot be quantified.[109] Maintenance decisions in industry are frequently influenced by irreducible considerations. Although many of these investments will not show a return on investment or some determinable economic advantage, they are considered necessary investments. This section will discuss corporate image, environmental considerations, employee relations, and quantification of irreducibles.

3.101 Corporate Image and "Showplace" Maintenance

Some large companies build and maintain large office buildings for their corporate headquarters. This is recognized to be done more for the building's prestige value than for economic reasons.[110] A vice-president of a large company with a headquarters building in New York wrote:

> "In comparing our maintenance costs with those buildings which are speculative, we know our costs are considerably higher. As an example, in most speculative buildings, if a breakdown occurs in heating or air conditioning, the time involved to replace the damage could involve discomfort to the occupants. In our case, the company's policy mandates that we provide sufficient maintenance and replacements to prevent discomfort to the occupants since they are generally all New York Life employees. With such a policy, maintenance costs can become secondary although within reasonable limits. Another example which might be interesting is the fact that we have provided backup generators at considerable expense because of the continuous electrical problems by the public utility. Not only did we provide backup power for emergency lighting and some elevator service but we provided a second generator to handle our computer equipment. These examples might point up the fact that an institutional building generally has to have a higher standard of maintenance and operation than other buildings."[111]

Most companies maintain certain facilities in very good condition as part of the selling strategy.(112) The purpose is to keep certain facilities in an outstanding condition so that potential customers may be given an impressive tour, thereby enhancing the company's possibility of a sale. Such places are often referred to as "showplaces."(113) Under these conditions companies perform work such as painting over existing paint that has sufficient protection quality left but is discolored. Under normal maintenance repainting would not occur, but under "showplace" conditions, it does.

3.102 Environmental Considerations

Pollution, public relations with community and aesthetics are considerations in maintenance expenditures. Good companies are conscientious of the community in which they exist and try to maintain facilities at a reasonable standard plus minimize their air and stream pollution.(114)

Many companies build and maintain their plants in a manner which ensures that the facilities will blend in with the physical background of the community as a whole. Good public relation efforts are carried out by maintenance expenditures which ensure the plant will not become an eyesore but a place in which the community can take pride.(115)

Companies are continuously scrutinizing existing facilities to ensure that pollution control measures are adequate. During an interview it was pointed out that pollution investments have become "necessity items."(116) The interviewee had an investment proposal for one and one-half million dollars to repair and modify the company's power plant to

"get rid of SO_2 and emissions of particulate matter." Although there was no way of making a company profit on the investment it had top priority.

3.103 Employee Relations

In industry, it is realized that facilities must not only provide safe and healthful working conditions plus adequate lighting, heating, and ventilating, but must also meet the psychological needs of the employee as well.(117) People are more sensitive to decor and aesthetics than ever before. As a result of social changes, many companies emphasize good working conditions in their recruitment of labor and in their effort to reduce employee turnover.(118) One plant engineer[1] stated during an interview that two prospective engineers had recently turned down job offers because the plant facilities were not air conditioned.

In a paper presented at the nineteenth annual National Plant Engineering and Maintenance Show, Sol King cited company considerations for employee comfort and convenience.(119)

(A) Air conditioning of all occupied areas;

(B) Excellent uniform lighting;

(C) Lounges, patios, locker rooms, etc., in or adjacent to each major work area;

(D) Adequate parking close to working areas;

(E) Good visual surroundings.

Providing these fringe items such as air conditioned spaces and clean attractive working areas add to the maintenance cost. But as one

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[1]Interviewee requested to remain anonymous.

corporate representative[1] emphasized, "If decisions are made to provide certain things then it is just as important to keep them up." According to most of the persons interviewed, the unions today play an important part in making sure certain facilities are well maintained.

3.104 Quantifying Irreducibles

Some items thought to be irreducibles can actually be quantified although some difficulty may be experienced with predicting exact numbers.[120] For example, it is now generally accepted that air conditioning in office buildings pays dividends in office efficiency.[121] Some industrial firms endeavor to quantify these items whenever possible. For example, an annual cost (initial cost plus additional maintenance costs) for an improved lighting system can be compared to the annual labor cost of the people affected to show what per cent increase in efficiency is needed to justify the investment. Post audits are sometimes applied to re-evaluate these calculations.

3.11 Annual Maintenance Expenditures Expressed as a Percentage of Investment

Experience factors in some industries can be used to estimate maintenance cost as a percentage of investment.[122] Annual maintenance cost for production equipment is estimated to run between seven and fifteen per cent while building maintenance should run approximately one and one-half to three per cent of investment.[123] For reasons such as considerable variation in accounting procedures and the variations included

[1]Interviewee requested to remain anonymous.

in the maintenance bill these figures are not considered to be reliable.(124)

Industrial interviews failed to uncover any firms that analyzed maintenance costs by the per cent of investment method. Only one interviewee would attempt to do so.[1] From an insurance company asset appraisal a rough estimate of real property value was compared with annual maintenance expenditures in this area. The figure calculated fell slightly short of one per cent. However, the interviewee did not know how the insurance company determined the values of the assets listed. This could make a difference in the value of the ratio obtained. For example, if the values were original investment costs a different value would be obtained than if they were replacement costs.

3.12 Summary

Management endeavors to distribute company monies so that the last dollar given to each unit of the organization returns the same value. In doing so it is achieving its maximum economic efficiency. When funds are limited, (as they usually are), departments are in a sense, competing for these funds. Management has to assess the value to be gained from the additional expenditure in each area and determine how to prorate its investments. An investment in maintenance, like other investments, must be recovered along with a minimum rate of return.

Methods of evaluating expenditures in private business are both good (present worth, annual cost, rate of return) and bad (intuitive

[1]This was not a company policy but a favor done for the author.

squeaky wheel, necessity, payout). In general, the decisions made for real property maintenance facilities appear to center around the latter. One exception is the expenditures made as capital investments.

A small amount of major repair work must be depreciated in accordance with federal tax regulations. When a repair cannot be expensed in the year accomplished, it is considered a capital expenditure. These projects are approved at the highest levels of management. In industry capital expenditures in the maintenance department are replacements and betterments.

Capital expenditure programs in private enterprise start with the submission of project proposals from all parts of the organizations. These "needs" usually exceed funds available and must be rationed. The popular method of rationing is to construct a demand schedule with projects placed in order of their prospective rate of return. This provides management with a visual picture of the projects offering the best profitability. Repair projects are cost reduction in nature with profitability being determined by comparing with consequences of not accomplishing work. Other factors such as timing and risk are considered by management in making final decisions as to which projects will be funded.

A review of project submittals in industry was presented by examining the appropriation request form used by a local company. For decision-making purposes management receives such vital information as: the anticipated return on investment; the effects of postponing the investment over a three year period; a synopsis of rejecting or approving; the economics for each of four different alternatives; personnel considerations; and disposal of old facilities.

Reasons for retirement of physical property in industry were presented. The aim of management is to replace property when it no longer contributes to the profitability of the organization. Maintenance expenditures usually increase with facility age. These costs, either alone or in combination with other operating costs, may justify replacement of certain items. Management realizes that old assets are not usually as valuable as when new due to: increasing maintenance and operating costs; shorter life expectancy; changed service conditions; and overall more expensive than an alternate. Analyses of potential alternatives are made on an annual cost basis using a minimum attractive rate of interest. The factors considered in these economic studies were presented including: the respective expected lives; depreciation and taxes; net realized value of old asset; initial cost of new; and the estimated future operation and maintenance cost of each.

The author discussed the application (or lack of) of economic analysis on smaller projects in industry and provided a simple example.

The concept of life cycle approach for facilities pointed to the advantages of designing, constructing, and maintaining physical assets in such a way as to minimize overall costs. In these situations, management was in an enviable position of being able to predict within reasonable limits when the facilities would be obsolete and abandoned.

Deferring maintenance was discussed and observed to be caused by the limited funds. This situation required management to make decisions among alternatives which will provide the greatest economic advantage to the company. Alternate decisions included: (A) do nothing and permit deterioration; (B) take measures to preserve status quo;

(C) correcting by strengthening; or (D) replace or abandon. In industry, the non-productive facilities usually are the first to be deferred. Items which adversely affect production and safety are rarely, if ever, deferred. The remainder of desirable work is then set in order of priority.

Industry appears to favor less annual cost for inspection and preventive maintenance and pay replacement costs at a later date. An example of this was given including the calculations of annual costs.

Federal tax structures were shown to encourage higher levels of maintenance and repair work during good economic periods.

Programs to determine the cause of deterioration prior to repairing and subsequent corrective action including better materials have resulted in considerable savings for some plants. Some examples of upgrading facilities were given.

A common economic decision in industry is whether to design and construct with a high initial investment and lower annual maintenance charges or vice-versa. In general, industry favors the higher first cost (which is certain) over higher future maintenance expenditures (which are uncertain). The growing rate of inflation was cited as the primary reason underlying this preference.

Past experiences of neglecting the maintainability of facilities when designed has led many companies to include an engineer for the maintenance area on new project committees.

Irreducible factors were introduced as having a tremendous influence on maintenance expenditures in industry. Corporations were shown to over maintain some facilities because of corporate image or part

of the selling strategy. Environmental considerations, likewise, have an impact on maintenance spending. Such items as pollution control, public relations with the community, and aesthetics require large expenditures to maintain the company in a condition acceptable with its neighbors.

A very important irreducible is the effort to provide and maintain facilities in a condition which meets the needs of the employee. The sensitivity of people to safe and comfortable working conditions is increasing. Employers have become more aware of these attitudes and endeavor to ensure whatever is necessary to reduce turnover and enhance labor recruitment. Efforts to quantify these irreducible elements were discussed.

Annual maintenance expenditures as a percentage of investment was explored. Results showed that rough estimates are available but that the figures are unreliable because of company variations.

4.0 INDEXES AND INDICATORS OF PLANT CONDITION

This chapter will introduce the indexes and indicators that the author found in use by some industrial firms. The method of employing each plant condition indicators will be described.

4.1 Reasons for Indexes

Indexes of some sort are used by many industrial plants as a barometer for measuring the effectiveness of their maintenance program. The most common indexes in industry are those which express maintenance cost as a function of:[125]

(A) Value of assets or capital investment;

(B) Units (pounds, tons, etc.) produced;

(C) Total manufacturing cost;

(D) Power consumed;

(E) Total conversion cost;

(F) Some combination of the above.

When used separately these indexes have limitations and, therefore, they are usually used in some combination.[126] This point and the difficulty in using an index as a comparison between plants or companies are best illustrated by the following quote from Maintenance Engineering Handbook:

> "Although many attempts have been made to arrive at a universal yardstick for financial performance of a maintenance department, it is generally accepted that there is no one index that can be used for this purpose. Each method of measurement has its exponents, but a close inspection reveals most of them to be tailored to the needs of a specific plant or company, or to be so indefinite as to be of little real value. In either

> case they are of little use as bases for comparison with other organizations. One of the major problems in establishing means of evaluation and comparison of performance for internal historical purposes or for comparison with other maintenance departments is the effect of company policy variables outside the control of the maintenance department. Differences in the use of these and similar variables enter into maintenance-cost measurement, whether it is presented as a function of capital invested, pounds pounded, dollars of manufacturing cost, power consumed, or per cent of total sales."(127)

A study of the trends of several indexes is usually accepted by management as more indicative of performance than value at any one time.(128)

4.2 Purpose of Plant Condition Indicators

Indicators of plant condition, on the other hand, are used to describe the physical condition of real property facilities. They are not as widely used as are indexes.

As discussed in Chapter Two, the proper level of maintenance for production equipment is established by determining the focal point at where any additional preventive maintenance cost would be greater than the benefits received by the reduction in downtime costs. The care of real property facilities, however, includes the more intangible factors such as plant appearance, plant safety, and personal comfort and convenience. The indexes discussed under 4.1 are cost oriented, i.e., they exhibit the cost relationship between maintenance and some other factor. However, they do not reflect plant condition. Indicators of plant condition are of particular interest to companies which have a centralized system of distributing maintenance funds or have an objective of maintaining plants at a comparable level of repair. Some of the indicators used in industry will be discussed further under 4.3.

At this time it should be pointed out that many companies have played with the idea of using indicators for comparing plants but satisfactory results were not achieved. One such case is reflected in a letter from one of the firms which responded to the questionnaire.

> "Our system is divided into twenty-three (23) Divisions and I have identified the Division as the "Plant" for the purpose of your questionnaire. We do not have a formula (BEMAR) with which we rate the condition of the one Division as opposed to another. Attempts have been made along this line but the many factors involved, the weight which should be applied to each factor, and the assembling of all this information into a meaningful formula has never been very successful. We do use a formula to rate the relative maintenance requirements of each Division which is based upon the tonnage moved over each Division along with certain physical characteristics of the Division. This is useful in determining the allocation of forces and Supervision for the day to day maintenance functions that must be performed but provides no comparison as to the condition of one "Plant" as opposed to another.
>
> I feel there is no substitute for having the maintenance officers at all levels, who are responsible for developing the annual program of maintenance work, to have a good first hand on-the-ground knowledge of the physical condition of the plant."(129)

Analysis of the questionnaires returned indicate that many firms have the same philosophy. Most of the replies show "visual inspection" or "judgment" to be a common denominator for comparing plants and that indicator formulas have not been utilized extensively for this purpose.

4.3 Examples of Plant Condition Indicators Used

The author will now present the only indicators of plant condition uncovered by the research methods employed for this thesis. For presentation purposes, the author has elected to call these separate methods: (A) the multiplant rating indicator; (B) the single plant

indicator; and (C) the multiple analysis indicator.

4.31 The Multiplant Rating Indicator

This system was developed by GENESCO of Nashville, Tennessee in 1961 and became fully operational in 1963.(130) A team of general maintenance engineers from the company's headquarters make an annual inspection of each plant. The plan requires that each plant be rated on a standard rating form[1] which is divided into three sections: (A) building exterior and grounds; (B) building interior; and (C) equipment. Each section contains several major components on these standard forms. For example, under "Building and Grounds" comes roofing, elevations, windows, access areas, landscaping, etc. Under each of these components are several items. For example, under roofing the following are listed: flashing; parapet walls; skylight; ductwork and air vents; roof surface; etc. On the rating form the inspectors assign point values to each item according to the following schedule:

10 Needs no special attention other than routine maintenance as due.

6 Routine maintenance (such as cleaning, lubrication or adjustment) is overdue.

4 Needs special attention above routine maintenance, requiring treatment with expendable materials (e.g., needs painting, caulking, surfacing).

2 Functioning but needs repair or replacement of components requiring installation (e.g., parts, lumber, switches, valves).

0 Not functioning.

The proper numerical value is written in on the form under the column "rating."[1] The "weight" factors are pre-printed on the form in two

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[1]See Appendix H

places; one for each major component (roofing, elevations, etc.), and one for each item listed under these components. The weight factors are assigned as follows:

10 Any factor directly affecting the health and safety of employees or relatively essential to operation of the plant.

8 Any factor which is necessary for prevention of wear and tear of machinery and which, if neglected, would result in expensive repairs.

3 Any item requiring regular attention and not covered in the two above.

1 Any item affecting the general appearance of plant or requiring attention irregularly as need arises.

The remarks column is used for stating reasons for downgrading any item rated below 10 points. The rating value is multiplied by the weight factor and this product is inserted under the points column. Items that are not applicable are crossed out. The sum of the points of each item under each major component is divided by the total of the weight factors. This is the grade for that major component.

$$\text{Component grade} = \frac{\text{(Rating of Items X Weight Factors)}}{\text{Weight Factors}}$$

The final grade for the plant would be calculated by multiplying each major component grade times its weight value; sum up these products; and divide this total by the sum of the weight factors of all the components.

$$\text{Final Grade} = \frac{\text{(Grade of Component X Weight)}}{\text{Component Weights}}$$

Based upon the final grade, each plant is assigned a rating AAA, AA, A, B, etc. Examples of final ratings are listed as follows:[131]

PLANT	DATE	GRADE	RATING
Frankfort	7-63	98.5	AAA
Fulton	4-63	88.2	A
Lewisburg	5-63	84.4	B
Atlanta	7-63	83.4	B
Huntsville	5-63	73.3	C

The company uses this information for setting maintenance budgets for each plant for the coming year.[1]

4.32 The Single Plant Indicator

This system is one used by B.F. Goodrich Company to rate each of its major real property facilities annually.(132) The indicator shows whether they are improving or downgrading these facilities.

Each facility is inspected annually by three or four people, usually the plant engineer, the supervising engineer of maintenance and representatives from the divisional and corporate engineering departments. Numerical scores are assigned to each component of the facility using a inspection check list.[2] Scoring is according to the following schedule: (A) top condition, ten points; (B) good serviceable condition, seven points; or (C) below standard, four points. Intermediate grades are assigned for "shading" areas. The scores of all inspectors are averaged for each facility, thereby providing a numerical grade. The facility grade is compared to the previous year's rating to determine progress. The numerical ratings of all facilities are then averaged to obtain a plant average. This, likewise, is compared with past years. Appendix I contains ratings sheets and comparison examples.

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[1]How the indicator was used for budget planning and allocation was not available.

[2]Appendix I contains a typical inspection check list.

4.33 Multiple Analysis Indicator

The multiple analysis approach is a method derived by Glidden Company in which four factors are examined for each plant, ever a three to five year period.[133] The four factors are historical costs, capital investment, production level, and manufacturing cost.

The historical cost analysis consists of looking at the maintenance cost trend for the period. For example, Plant A may show a $10,000 per year increase while Plant B has remained constant until a $10,000 increase the past year. On the surface it might appear that Plant B is doing the most acceptable job.

The second factor, capital investment, is then examined. This is accomplished by looking at the maintenance cost as a percentage of investment. This will provide a trend for this ratio. Plant A may be remaining constant while Plant B has shown a declining trend with a recent upturn.

The production level is then analyzed. This is shown as a maintenance cost per unit produced. The fourth factor is examined by expressing maintenance cost as a percentage of manufacturing cost. This factor may show that Plant A has a downward trend while Plant B has a slight upward movement.

The main feature of this system is that the multiple approach helps identify possible over maintaining or under maintaining of plants. In the example, it might be expected that Plant B had been deferring maintenance in past years and that future years cost may show further increases.

4.4 Discussion of Plant Indicators in Use

The multiplant rating indicator and the single plant indicator represent annual inspection reports by corporate engineers. The indicators are based on assigned numerical values according to a predetermined point spread. The indicators are not related to the cost of repair or the extent of the deficiencies. The results reflect only the judgment of the inspectors and possess the distinct disadvantage of obtaining different results each time the task is accomplished by other inspecting personnel.

The multiple approach indicator is cost related and in that respect has an advantage over the other two methods. The method is, however, more applicable to production assets than it is to only real property type facilities.

4.5 Summary

Indexes were shown to be a barometer used internally by some companies to measure the effectiveness of their maintenance program. Indexes used usually express maintenance costs as a function of some variable such as capital investment, kilowatts of power, units produced, etc. The most acceptable method of using indexes is to use more than one variable and to examine trends rather than looking at one specific value at any one time.

Indicators of plant condition were explained as being more related to the physical condition of real property facilities. It was shown that plant condition indicators are not as widely used as indexes

and that some companies have tried unsuccessfully to use them.

The research for this thesis uncovered three indicators that were being used. These were: (a) the multiplant rating indicator; (b) the single plant indicator; and (c) the multiple analysis indicator. The application of all three indicators as used by their respective organizations was presented. The first two were seen as rating systems based upon the subjective opinion of a team of inspectors. In both cases, the method did not explore or relate the indicator to a cost. The third method analyzed four factors which were related to cost but were more adaptable to productive assets.

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The Naval Facilities Engineering Command (NAVFAC) is responsible for the technical direction of the alteration, repair, and estimate of funds required for the maintenance of Public Works, Public Utilities and Civil Works in the Navy. At the individual base levels, the responsibility for the management and control of maintenance and operation of public works and public utilities is delegated to the Public Works Officer by the Commanding Officer. Within available resources the Public Works Department endeavors to perform this task in the most efficient and economical way possible.

In recent years the NAVFAC organization has expressed great concern over the inadequacy of funding and the declining condition of real property facilities. In an attempt to gain support for increasing budget requests, NAVFAC has used an indicator of plant condition called BEMAR which is a ratio of major repair projects greater than ten thousand dollars to current plant value. This indicator has not been widely accepted and each year the appropriation becomes smaller. NAVFAC has to prove the validity of BEMAR or continue its search for a new indicator.

Another effort to support budget needs has been a comparison of Navy funding with industrial standards. Since private industry is in a competitive environment its expenditures for maintenance would appear to be most economical and such a comparison could help support the requested funding levels. Looking at industry is yet another way of examining

the economics of Navy maintenance management. This thesis presents what the author found in industry with emphasis on economic aspects. A search for a new indicator was also made and findings are presented.

A tremendous amount of variation exists throughout industry among its maintenance organizations and programs. Companies produce different products, under different managements, each having different requirements. It is generally accepted that maintenance programs will not be exactly the same for any two plants. Methods of classifying work, cost accounting procedures, management policies, etc., all lead to a fruitless effort when trying to compare costs or other criteria.

The use of expressing annual maintenance costs as a percent of investment is not very popular for budgeting - allocation purposes. Rough estimates are available but are not considered reliable due to the variations in defining work categories and assigning costs.

The objectives of maintenance management are: (A) protect the company's capital investment and increase profits; (B) increase production by minimizing unscheduled breakdowns; (C) lower manufacturing costs; (D) protect quality standards and (E) maintain safety standards for preventing injury to personnel and damage to properties.

Top management in a competitive business distributes its limited resources in a manner that will ensure maximum economic efficiency. The investment made for maintenance must provide the same return as an investment elsewhere. Annual budgets for maintenance and repair work are provided on this basis. The non-project (recurring, ordinary) work is the day-to-day plant upkeep necessary for continuous operation. Under normal conditions, funds necessary for this work will always be made

available. Project (non-recurring, extraordinary) work will be funded depending on need, profitability, and economic conditions. Each company has its own separate procedures for this type of project funding but normally a dollar value is established depending on what it can afford during the coming year. In periods of good profits companies will normally do more maintenance and repair work. Federal tax regulations are structured as to encourage higher maintenance expenditures, especially in prosperous times. During depréssive business periods facility maintenance is usually curtailed and repair projects deferred. Items which will have the lesser effect on profitability are deferred first.

Each company within the peculiarity of its own policies and philosophy sets a level of maintenance. Engineers and management are usually at odds upon what is the proper level.

For the most part industrial maintenance is divided into two main categories; productive and non-productive. Productive units are directly related to production and are more receptive to measurement in respect to profit. This permits an easier solution for setting the economic level of maintenance. This is accomplished by determining an optimum point where any additional expenditure for planned maintenance will not be recovered by the amount of reduced breakdown time. These maintenance costs usually run 70 to 75 per cent of the total maintenance budget. The maintenance budget ranges between three and fifteen per cent of the company's budget.

In industry it is common to identify items as being critical. This is particularly true of production assets. If a unit of property would adversely affect production and profitability and if an unscheduled

breakdown occurred then it would qualify as a critical unit. The same is true of safety being threatened or severe damage to property. These critical units will receive preventive maintenance attention while property not qualifying will receive a lesser degree of care such as breakdown maintenance.

Real property facilities are not directly related to production and are, to a large degree, taken care of on a breakdown or corrective maintenance basis. Since these properties do not normally effect production directly the inspection and preventive maintenance effort is minimal. Some lower priced facilities and some structural components are cheaper to replace periodically than to provide intensive maintenance attention. Excessive maintenance is found to do little more than prolong the life of the facility. This varies with the nature of the product. If certain real properties are related to the product then maintenance effort is greater. In general, written maintenance policies and guides or standards are non existant for non-productive assets. This is with the exception of most equipment such as air-conditioners, where recommendations of the manufacturers are followed. Full-time inspectors are not normally employed for inspecting real property facilities. Maintenance expenditures in the non-productive area range between 5 to 15 per cent of the maintenance budget.

Indirect maintenance costs for rearrangements, alterations, betterments, etc., have a very large spread of about 15 to 35 per cent of the maintenance charges.

The competitive environment of businesses require a continuous process of improving and replacing facilities which retard profitability

or give advantage to competitors. Many of these projects must be funded as capital expenditures and are subjected to a scrutinizing review by top management. Capital expenditure projects are rated according to their prospective rate-of-return. Other factors such as risk and timing are considered in reaching final decisions for approval. Project submittals required the following information: the anticipated return on investment; postponability consequences over a period of time; a synopsis of results predicted for approval or rejection of project; the economics calculated for known alternatives; irreducible data; and the proposed disposal of old facility. Old facilities are sold or disposed of in some manner to ensure monies are not required for their support. Retention must be fully justified.

Maintenance and repair costs increase with age of facilities. In industry these expenses either alone or in combination with other costs can justify replacements. Economic studies are made to determine the over-all profitability of undertaking a replacement project. The annual cost method is most popular for these studies since the two alternatives will probably have different life expectancies and more people understand the annual cost concept. Factors considered in the studies include: expected life of alternatives; investment cost; net realized value of old facility; future operations and maintenance costs for both; and taxes and depreciation for capital expenditure items.

Industry takes advantage of situations when the obsolescence of a facility can be predicted with reasonable accuracy. Facilities are designed, constructed, and maintained at a minimum overall cost. At the end of the intended life management is not concerned if the facility is

ready to collapse since the structure has served its purpose and the investment has been recovered. Facilities constructed for an indefinite period of use are designed and constructed with higher initial investments and lower future maintenance expenditures. Maintenance engineers are frequently assigned as members of a project planning committee to insure that a reasonable degree of maintainability is incorporated into the design.

Private businesses use well kept facilities as part of a sales strategy or corporate image philosophy. Better public relations are enhanced if the company can maintain a plant which blends in appropriately with the neighborhood and community. This includes an effort to prevent pollution of the atmosphere and streams by keeping facilities in good working condition and upgrading when necessary.

Employee relations has an impact on the maintenance level in industry. Safe, clean, and comfortable working conditions have an effect on productivity, employee turnover, and recruitment effort. Some firms have made attempts at quantifying these irreducibles.

Three indicators of plant condition were found: (A) the multiplant rating indicator; (B) the single plant indicator; and (C) the multiple analysis indicator. The first two indicators were basically a composite inspection report prepared by a team of engineers from plant, division, and corporate levels. The values obtained were based upon the subjective judgment of the team. These indicators were not cost related. The multiple analysis indicator was cost oriented but also more applicable to production maintenance costs than to real property facilities. The approach does have the important feature of carefully analyzing costs from different angles.

5.2 Conclusions

The objective of this thesis was to represent interested Navy personnel with the background of maintenance management in industry. This was due to the Navy's periodic use of industrial standards in examining its own maintenance needs. The contents of this thesis has provided that information. Other objectives included: a review of economic and irreducible factors considered in industry; a search for a real property plant condition indicator; and the applicability of any of the techniques used for improving the Navy system. The following conclusions represent a synopsis of findings which are considered pertinent in meeting these objectives.

In the private sector of the economy businessmen distribute available resources in a manner which will maximize benefits. Maintenance dollars are allocated based on what return will be forthcoming compared to using the funds for alternative investments. Additional budget requests to management must be sold to top management on a cost versus savings basis. Top management in the Navy likewise must allocate its resources in such a way that it will receive maximum benefit from the limited resources available. Maintenance dollars for Navy real property are made based on what they show in return for a dollar spent. Extra maintenance dollars will have to be justified as being more valuable than alternate uses.

The main objective of maintenance management in industry is to protect the company's most expensive assets at a minimum cost over the maximum time of producing a quality product. This is accomplished in a way that contributes to the optimizing of corporate profits. The amount

of money that is made available for maintenance is a function of the company's profit position. The essential and safety requirements are funded. Other desirable projects are accomplished within residual funds available. During periods of poor economic conditions less projects will be accomplished and a greater number will be deferred. The opposite is true in prosperous times. Federal tax regulations are a minor factor considered in industrial maintenance decisions. The Navy does not produce market products; does not make a profit; and does not pay taxes. NAVFAC does, however, have the maintenance objective of optimizing the use of available resources for providing effective support to the fleet by insuring facilities are maintained at the proper level or standard.[134]

In industry, productive units receive much higher maintenance attention than do the real property type facilities. Buildings are looked upon as shells for housing productive units and, therefore, maintenance is extremely austere. Inspection of non-productive facilities ranges from very low-keyed to non-existent. Full-time inspectors for real property is usually not found in industry. By economic analysis on an annual cost basis, some facilities are intentionally by-passed for maintenance as periodic replacement is cheaper. Most of the real property facilities are taken care of on a breakdown or corrective maintenance basis. In contrast, the Navy employs an extensive preventive maintenance program and has a continuous inspection service for real property facilities.[135] Efforts are made to ensure all facilities are inspected a minimum of once annually, and facilities are, within available resources, brought up to a proper level of maintenance as a result of this inspection.

In private business, analysts are able to determine operation costs and maintenance costs and relate them with profit in replacement decisions. In the Navy, each is looked at separately with either one, individually, required to justify replacement. Industry, therefore, has the advantage of being able to look at the two costs together for justifying replacements. Under BEMAR, the Navy has called its backlog projects essential but some decision makers indicate that there appears to be no apparent adverse effects from not accomplishing them.[136] What is really being said is that operators change their operations in a way that accommodates to these deficiencies. Therefore, the adverse effects are avoided or adjusted to existing conditions with operational losses not being reported or known. The Navy, unlike industry, does not use operation inefficiencies in conjunction with maintenance costs for repair and replacement decisions.

Capital expenditures in private business are well developed and give executive management the best available data for making sound investment decisions. The demand schedule is a good device for presenting the economic advantages of one proposal in relationship to others. The forms used by industry for major investments have many outstanding features which contribute to good sound management decisions. Economic analysis are made using many factors which provide the information of the lowest cost method. In contrast, the Navy Military Construction projects[1] and Special Project Requests[2] provide essentially no cost data but the investment for the new facility and the cost of repair. Not

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[1]See Appendix J.
[2]See Appendix K.

enough information is given for making a sound economic decision. Projects do not include the cost of deferring the project nor anything regarding the economics of timing. The present proposal procedures and forms fail to provide management with the information regarding future implications of their decisions.

Industry favors high first cost for construction and lower annual maintenance when facilities are planned to be used for an indefinite period of time. When facilities are known to have a short life cycle then cheaper construction material will be incorporated into the structure and maintained to last that duration. Extension of facility life through maintenance can be uneconomical. The Navy has made life-cycle studies for Bachelor Enlisted Men's housing facilities and initial results are that a less permanent facility with higher annual maintenance expenditures are overall cheaper.(137) Three things make the NAVFAC initial reactions unsound at this time. First, industrial results indicate otherwise unless the obsolescence period is short and predictable. Secondly, the Navy already expresses concern over a lack of funding for real property facilities. And lastly, the present project proposal systems fail to provide the decision makers with the future maintenance implications of their decision.

Industry is encouraged by its objective of maximizing profits to dispose of real property facilities which do not contribute to this goal. By disposing of these facilities private business rid themselves of assets which would otherwise require a certain amount of their resources for operations and maintenance.

One exception to an extremely austere maintenance program of real property is the amount spent on certain facilities which enhance corporate image, sales, and employee relations. However, these costs are felt to be recovered by management. Industry has experienced that providing and maintaining good facilities have increased worker productivity, improved recruiting efforts, and reduced employee turnover. Efforts of quantifying results have illustrated their profitability.

Cost figures, percentages, averages and other data available on maintenance costs in industry are not reliable due to the tremendous variations in industry. Reasons for the variety are due to: management policies and philosophies; classification of work; cost accounting procedures; etc. The data available is not worthy of use by the Navy in supporting their maintenance program.

Indicators of plant condition are very rarely utilized by industrial firms. The thesis research failed to disclose the existence of any indicator superior to BEMAR. The ones found lack an engineering approach and represent little more than a subjective field inspection report. The indicators used are not cost related and of no value for NAVFAC's requirements.

The multiple analysis approach did stimulate some thought regarding BEMAR and although not directly related to this thesis, it deserves mentioning. BEMAR should be analyzed from the viewpoint of the incremental portions. By this the author means to determine: (A) what is the change in the repair cost of projects being held over from the previous year; (B) what amount of the increase in BEMAR is new projects; (C) what is the value of the projects deleted by repair and by demolition;

and (D) what do post audits of projects repaired show in the line of cost of deferring. The projects must also be analyzed by type of work. This is necessary because it will indicate whether the projects are usually of the same nature and are due to misguided funding procedures. As an example, if road work is a frequent item, it could be found that small annual appropriations are made and are not used because the base personnel are not qualified or it is not economical to contract for small areas. The annual funds are then spent elsewhere.

5.3 Recommendations

It is recommended that NAVFAC justify additional funding for real property maintenance by establishing a cost versus saving relationship through post auditing of projects which have been deferred.

It is also recommended that the Navy run pilot tests on some lower priced units and certain building components, such as roofs, to determine if greater economies could not be achieved by lower annual inspecting and maintenance costs and higher one-time replacements.

The Navy should adopt a new project proposal procedure and form which will provide decision-makers with the economic criteria required for good decision-making. The new form should include the economics of alternatives, the economics of timing, and future cost implications. In replacement and repair projects, operational losses should be determined along with maintenance expenditures so that a realistic result will be obtained and, therefore, overall lower costs.

It is recommended that long term facilities be constructed with low maintainability costs until management practices are such that

decision-makers know the full consequences of life-cycle cost techniques.

It is recommended that the Navy make an all out effort to reduce their real property inventory to an absolute minimum similar to industry. This would make the money, which is required for maintaining them in a safe condition until demolition, available for the upkeep of essential items. In the same light, the current policy of reducing the Navy to a smaller and more efficient force should induce a study to determine which facilities will no longer be required. Efforts should be made to dispose of these facilities as soon as possible rather than to allow maintenance funds to be swallowed up over an extended period of time.

It is recommended that a future Navy Civil Engineer Corps Officer attending the University of Pittsburgh make a research thesis out of a multiple analysis of BEMAR as outlined in the Conclusions.

NAVFAC should initiate studies to determine what effect deteriorated, uncomfortable, and substandard living quarters, working areas have on reenlistment decisions. The findings should be quantified and added to the costs developed by engineering analysis to determine the true economic impact of under maintaining facilities. With the age of a total voluntary military rapidly approaching, there is little doubt that such a program is a necessity. Local commanders to Congressmen will undoubtedly provide more adequate funding for proper maintenance if statistics proved it to be a major retention factor. Such information should help to revise outmoded regulations which have prohibited items of comfort, such as air conditioning, in the past.

NAVFAC should refrain from using so called "industrial standards or averages" in support of their budget requests for maintenance.

Present criteria available is not reliable and its inclusion serves no useful purpose. The Navy should support its maintenance budget by justification of needs using good engineering, sound economics and modern management techniques.

The investigation and adoption of these recommendations should be most valuable in improving the maintenance management system for real property of the Navy.

APPENDIX A

DEFINITIONS OF PUBLIC WORKS AND PUBLIC UTILITIES

Public Works

The term "public works" at a naval shore activity applies to the buildings and structures including permanent fixtures therein and all fixed equipment pertaining thereto.

The following types of buildings, structures, fixtures, and equipment are classified as public works:

Airfields, complete with paving, lighting, and markers

Ammunition storage facilities

Amphibious pontoon equipment

Bridges and causeways

Buildings, including furniture, fixed equipment and elevators, but excluding shop tools and equipment

Coal unloading, handling, and storage plants

Communication station and systems, such as radio, telephone, telegraph, fire alarm, exclusive of electronic operating equipment

Docking facilities, including graving docks, floating drydocks, marine railways and lifts, and auxiliary equipment afloat and ashore

Foundations, structures, and towers for special purposes

Gas generation, storage, and distribution systems

Harbor improvements, including breakwaters, jetties, moorings, and dredging

Petroleum, oil, and lubricant storage and distribution systems, including pipe lines, and foam and other protective systems

Railroads, exclusive of rolling stock and car ferries

Refrigeration plants

Refuse disposal plants

Roads, pavements, walks, and grounds

Sewer systems, including treatment and disposal plants

Shipbuilding ways

Storm drainage systems

Target ranges

Walls and fences

Water collection, storage, treatment, pumping plants, and distribution systems

Waterfront facilities, including dikes, camels, floats, landings, piers, slips, quay walls, seaplane ramps, and wharves

Public Utilities

Public utilities refer to the fixed facilities and systems which provide major utilities' services at naval shore activities and generally include the following:

Telephone systems

Electric power supply generation and distribution systems

Water supply treatment and distribution systems including systems for fire protection

Heating systems, steam, hot water and others over 750,000 PTU/hr.

Sewage collection, treatment and disposal facilities

Refuse and garbage collection, processing and disposal

Air conditioning equipment and plants with a capacity of five tons and over

Ice manufacturing equipment and cold storage plants operated by public works departments

Exterior separate alarm systems -- both local and central reporting types

Gas generating plants, storage facilities and transmission lines (natural and manufacturing)

Compressed air plants and systems

Miscellaneous utilities, including central dehumidification and hydraulic systems, acetylene and oxygen generating plants.

APPENDIX B

SUBJECT: Industry Comparisons of Maintenance Costs Related to Plant Replacement Value

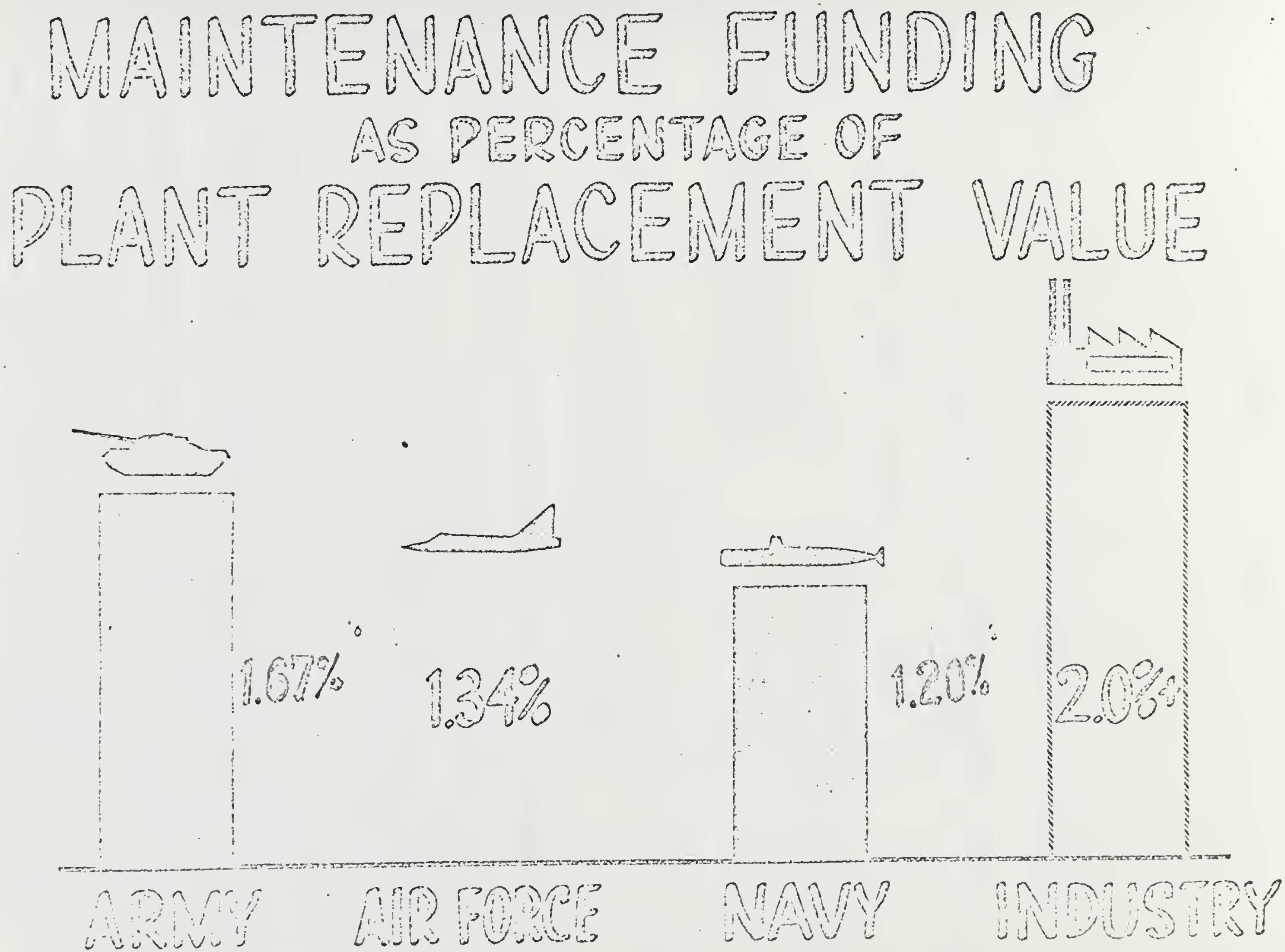
BACKGROUND: Comparisons with industry serve as another measure of Navy real property maintenance requirements.

DISCUSSION: (a) Several major corporations were contacted with results shown:

CORPORATION	MAINTENANCE COSTS
Union Carbide	4% of capital investment
Ford Motor Co. (Mr. Dewey)	10% of acquisition
Chrysler Motor Co.	(None)
Standard of Ohio	Maintenance Costs in a group of a dozen refineries range from 2.9% to 4% of replacement value (Source: 1959 PM & E Proceedings)
Catalytic Constr. Co.	Range for 1.5% to 5% of replacement value
DuPont	(1) Buildings, Research Labs, Manufacturing Plants, Office Utilities 7% - 8% replacement value. (2) Manufacturing Plants 10% to 11% replacement value. (3) Utilities 1% to 3% replacement value.

(b) A conservative figure (based primarily on DuPont) of 2% PRV is considered a reasonable estimate of industry practices.

PROBLEM: Most industries that keep records of maintenance costs per se do not have a plant replacement value available. Many others have plant values (acquisition or replacement) that include shop and production equipment. Few industries have plant property including airfield paving and extensive water-front facilities.


MAINTENANCE FUNDING
AS PERCENTAGE OF
PLANT REPLACEMENT VALUE
1.67%
1.34%
1.20%
2.0%+
ARMY
AIR FORCE
NAVY
INDUSTRY

APPENDIX C

QUESTIONNAIRE - REAL PROPERTY MAINTENANCE MANAGEMENT

I GENERAL INFORMATION

1. Company's name______________________________

2. City________________ State________________

3. Number of locations where plants (real property facilities are located________(United States and Foreign)

4. Do you feel that maintenance forces and funds are being used on the most important and most essential work at all times:
   ____yes ____no
   If not, approximately what per cent of the time? ____%

5. In your opinion, is the amount of facilities maintenance and repair work
   ____too high (over maintained)
   ____adequate (proper amount)
   ____too low (under maintained)

II MAINTENANCE DECISIONS IN GENERAL

1. How often are real property facilities (buildings, structures, utilities, etc.) inspected?________________________
   ____

2. What method or process is used to determine which major repair projects are going to be funded and accomplished?________________
   ____
   ____

3. When maintenance and repair work is considered to be essential, is the essentiality from an engineering judgment viewpoint____________ or from an operational viewpoint?________________________

4. What factors are considered in determining essentiality?____________
   ____
   ____

5. Are maintenance and repair projects forced to compete for funds with other company investments on their prospective rate of return?
   ____yes ____no

6. Do major repair projects require a higher rate of return than other investments?____higher ____lower ____same rate
If other than "same rate", what is the incremental difference necessary?____

7. When facilities are not maintained from an engineering viewpoint and this work deferred, has it been your experience that earlier replacement of that facility results and causes
____higher total costs
____lower total costs
____sometimes higher, sometimes lower

8. Are there any circumstances whereby your firm defers maintenance and repair projects when such deferral will result in accelerated deterioration? ____yes ____no
If so, could you give an example.______________________________
____
____

9. How is the cost of deferral determined?______________________
____
____

10. Are costs of "make-due repairs" in order to defer repairs added to the ultimate cost of work? ____yes ____no

11. Do you have any factors (percentage of cost) which are used for estimating the cost of accelerated deterioration when something is deferred? ____% of current facility replacement value.

12. Any factor (percentage of cost) for estimating costs of aging plant?
____%

13. What are the first things to be deferred when funds are tight?______
____

14. Would the firm retain production personnel not essentially required during lean times and neglect maintenance and repair ____. Or would the people be let go and the maintenance and repair work accomplished?
____first policy ____second policy

15. What priority does maintenance and repair have within the company?
____very high ____high ____moderate ____low ____very low

III DECISION MAKING CENTERS AND BUDGETING

1. Are funds for real property maintenance based on
   ____past experience
   ____last years budget
   ____justified current needs
   Is your answer the same for normal recurring maintenance of real property facilities?____________________

2. At what level in your organization is the decision regarding "repair now or defer or delete" made?____________________

3. Do you have a model or method for determining the costs of deferring maintenance work? ____yes ____no
   Could you describe it?____________________
   ____
   ____

4. Are all decisions regarding funding of maintenance and repair (regardless of size) made at the same level? ____yes ____no

5. Does company policy require Board of Director approval on investments over a certain dollar value? ____yes ____no What amount? $________

6. Does this same rule apply to maintenance and repair type of investments? ____yes ____no

7. Is the budgetary process for maintenance decentralized and determined independently by each plant? ____ Or is this method a centralized process at the company headquarters? ____

8. Does each plant receive an annual budget for maintenance and repair work? ____yes ____no

9. Is this budget based on unit costs and the number of units at each individual plant? ____yes ____no

10. Is the top executive in charge of each plant (location) authorized to spend whatever he deems necessary on maintenance and repair projects? ____yes ____no
    Is there a dollar limitation? ____yes ____no What is it? $________

11. Are Plant Managers (highest local company official) provided with a total budget from the directors to be used according to requirements as he sees them? ____yes ____no
    Are Plant Managers given earmarked allotments in different expenditure categories? ____yes ____no

12. Does your system preclude local adjustment of maintenance efforts to accommodate unforeseen exigencies? ____yes ____no

13. Is a priority list of required major repair work at each respective plant determined by each plant manager or by a centralized decision making process? ____each plant ____centralized

IV PROCEDURES, SYSTEMS, AND INDICATORS

1. Do you currently have what you consider to be a backlog of essential maintenance? ____yes ____no

2. Is there an existing target for reduction of the backlog?____________

3. Under current company policy does the present backlog represent more than one year's work? ____yes ____no

4. Does your firm have an indicator of real property condition (such as BEMAR) in use? ____yes ____no ____do not know
   If not, what method is used to ascertain condition?________________
   ____
   ____
   If so, what is your indicator?______________________________
   ____
   ____

5. Do you use current plant value or plant replacement value compared to estimated cost or repair?______________________________

6. Do you use this indicator in determining how to allocate resources for maintenance and repair work among your various plants?__________

7. Does your indicator or system establish a guide to the relative priority of work that needs to be accomplished? ____yes ____no

8. Do you feel that your company has a uniform and systematic method for evaluating and comparing real property facilities between different plants? ____yes ____no
   Between facilities within each plant? ____yes ____no

9. In your opinion, does your system provide or assure an excellent and equitable distribution of maintenance resources? ____yes ____no

10. Is it the objective of your system to insure that facilities at all plants (locations) are maintained at the same level of repair? ____yes ____no Comments______________________________

11. Do you employ a standard for comparing one plant with all others? ____yes ____no

12. What common denominator do you use for this comparison?____________
    ____

V ECONOMIC ASPECTS

1. In economic studies involving major repair projects, what interest rate is used for calculating the cost of using funds for maintenance and repair projects?________________________________

2. What is the current cost of borrowing money?________________________

3. Do you ever borrow money to perform maintenance work? ____yes ____no

4. Is the cost of a major repair amortized over the expected life of the repair job? ____yes ____no

5. Are projects updated periodically to adjust for increases in labor costs, material costs, etc.? ____yes ____no

6. What three factors do you think effect real property maintenance costs the most?
   1.____
   2.____
   3.____

7. What steps do you take when new facilities are designed and constructed in order to minimize future maintenance costs?

8. Do tax advantages play an important part in your determining whether or not certain maintenance and repair will be performed?
   ____major role
   ____minor role
   ____not considered

APPENDIX D

CORPORATIONS SELECTED FOR MAINTENANCE SURVEY

1. Aluminum Company of America
2. American Telephone and Telegraph Company
3. Bank of America
4. Bethlehem Steel Corporation
5. Catalytic Construction Company
6. Caterpillar Tractor Company
7. Chrysler Corporation
8. Cincinnati Milling Machine Company
9. Clark Equipment Company
10. Delta Air Lines, Incorporated
11. Dow Chemical Company
12. Dravo Corporation
13. Duquesne Light Company
14. Eastman Kodak Company
15. E.I. duPont de NeMours and Company
16. Ford Motor Company
17. General Electric Company
18. General Motors Corporation
19. General Telephone and Electronics Corporation
20. Goodyear Tire and Rubber Company
21. Gulf Oil Corporation
22. Holiday Inns, Incorporated
23. Howard Johnson Company
24. Hyster Company

25. International Business Machines Corporation
26. International Telephone and Telegraph Corporation
27. Johns-Manville Corporation
28. Jones and Laughlin Steel Corporation
29. Litton Industries, Incorporated
30. Mobil Oil Corporation
31. Mutual of Omaha Insurance Company
32. New York Life Insurance Company
33. Penn Central Company
34. J.C. Penney Company, Incorporated
35. Pennsylvania Drilling Company
36. Peoples Gas Company
37. Phillips Petroleum Company
38. Pittsburgh Bridge and Iron Works
39. Procter and Gamble Company
40. Ralston Purina Company
41. RCA Corporation
42. Santa Fe Trail Transporation Company
43. Sears Roebuck and Company
44. Shell Oil Company
45. Southern California Edison
46. Standard Oil Company (New Jersey)
47. Tenneco, Incorporated
48. Texaco, Incorporated
49. Trane Company
50. Trans World Airlines, Incorporated

51. Union Carbide Corporation
52. Union Oil Company of California
53. Union Pacific Railroad
54. United Air Lines, Incorporated
55. United States Steel Corporation
56. Walter Kidde and Company, Incorporated
57. Walter Kidde Constructors, Incorporated
58. Warner and Swasey Company
59. Western Electric Company, Incorporated
60. Westinghouse Electric Company, Incorporated
61. Zerox Corporation

C-O-P-Y

APPENDIX E

EXTRAORDINARY MAINTENANCE PROJECTS FOR 1969

LOCATION AND DESCRIPTION		ESTIMATED COST-1969	DISPOSITION OR APPROVAL OF
N-3 BUILDING			
1.	Replacement of all the old steel sash on the Grand Avenue side, first and second floors. Twenty windows at $795.00/ea.	15,900	
(1-A)	(Alternate - (6) Year Program. Replace (6) windows at $1,050)	(6,300)	
RAILROAD			
1.	Line and grade on runaround north of Grand Avenue.		
2.	Tie replacement south of new Tailhouse (200 ties at $10.00/ea.).	4,000	
3.	Tie plates and ballast renewal.		
PARKING LOTS AND ROADWAYS			
1.	Roadway improvement and addition in N-10 marshalling area, and N-11 (1,050 sq. yds. @ $4.00/sq. yd.).	4,200	
2.	Replace wooden parking lot car stops with cement stops.	5,500	
3.	Grade and spot patch 10,000 sq. yds. at 42¢/sq. yd. for roadway breakup. (Last repair was 5/4/64).	4,200	
MACHINE SHOP			
1.	Replace all of the 1942 wood sash on south east side of shop with opening and closing Alumasash.	12,000	
(1-A)	(Alternate - 50% replacement).	(6,550)	

LOCATION AND DESCRIPTION		ESTIMATED COST-1969	DISPOSITION OR APPROVAL OF
MACHINE SHOP - continued			
2.	Window washing (Last done 4/16/53).	3,300	
3.	Continuation of Skylight repairs (188 lights).	15,000	
STRUCTURAL SHOP			
1.	Window washing, entire shop, acid cleaning is necessary with possible exception to the west wall of the Headhouse which would be $3,000 less than the $8,000 shown. (Last done 12/18/53).	8,000	
COMPRESSOR HOUSE			
1.	Recondition entire roof. (Bad shape) (3,280 sq. ft. area) (Last done - 6/28/54).	1,750	
N-9 SMOKE STACK			
1.	Repair 1/2" wide crack that extends down from top of stack 21 ft., rake out & tuck point any bad joints, check lightening conductor system & repair if necessary, then apply (1) coat of silicone water-proofing over the entire surface.	1,450	
(Alternate) (1-A)	Remove upper 30' of chimney, reattach lightening conductor to new concrete cap, repair all joints and apply (1) coat of silicone, remove all debris from premises.	2,250	
OLD BARGE SHOP (BUILDING 42)			
1.	Recondition entire roof (very bad condition). (38,880 sq. ft. area) (Last done 5/23/61).	15,550	
N-10 WAREHOUSE			
1.	Recondition entire roof (needed now). (37,960 sq. ft. area) (Last done 5/16/62).	4,700	

LOCATION AND DESCRIPTION		ESTIMATED COST-1969	DISPOSITION OR APPROVAL OF
WATER TOWER (top portion last done 5/17/62). (Bottom portion last done 7/3/58).			
1.	Wire brush, spot prime, one full prime coat and (1) full finish coat to the entire water tower and reletter all Dravo signs on tank sides.	5,500	
BARGE SHOP (BUILDING 42)			
1.	Wire brush (1) full prime coat and (1) full finish coat to the entire portion of the Old Barge Shop. This will include re-glazing all broken or missing sash lights. (Last painted 5/23/61)	10,800	
STEEL YARD (Last done 5/11/60)			
1.	Sandblast all overhead crane structural steel support legs and runways down to bare metal or to firm sound paint and apply (1) spot prime, (1) full prime coat, and (1) finish coat to all sandblasted surfaces.	25,500	
	(NOTE:) This approach is highly recommended because of the advanced state of rusting and paint blistering.)		
(1-A)	Alternate approach for the crane runways would be to clean locally with wire brush or scraper and solvents. Apply (1) spot prime, (1) full prime and (1) full finish coat. (This is not recommended because of the almost inaccessability of some areas to be cleaned properly and the generally unsound, thick and unmarried condition of the paint in many other areas. Please note photos.)	22,500	
N-13 BUILDING			
1.	Recondition entire roof (needed now). (15,000 sq. ft. area) (Last done 5/16/62).	3,000	
SHORT DOCK (D.C.)			
1.	Replace wooden rub timbers with rubber "Tonees", relocate access ladders to fleet & reattach handrail.	4,300	

APPENDIX F

APPROPRIATION REQUEST

ORIGINAL ☐ REVISION ☐ APPROPRIATION NO.________

DIVISION	FACILITIES CLASS NO. & NAME	PRODUCT LINE(S)	CLOSING DATE

PROJECT TITLE

BRIEF DESCRIPTION OF PROJECT IN TERMS OF THE ACTIONS TO BE TAKEN.

RETURN ON INVESTMENT______% WITH TERMINAL VALUE,______% EXCLUDING TERMINAL VALUE

ESTIMATED COST	ORIGINAL AMOUNT	AMOUNT OF REVISION	REVISED AMOUNT
SCHEDULE A - DURABLE EQUIPMENT			
SCHEDULE C - LAND AND BUILDINGS			
SCHEDULE D - EXPENSE			
APPROPRIATION TOTAL			
______YEAR LEASE COMMITMENT			

		THIS YEAR	NEXT YEAR	FOLLOWING YEAR
ESTIMATED TIMING OF EXPENDITURES	CAPITAL			
	EXPENSE			
	LEASE COST			

THE FUNDS FOR THIS APPROPRIATION ARE ANTICIPATED IN THE FACILITIES INVESTMENT PLAN, SUBMITTED FOR CURRENT YEAR, IN THE AMOUNT (000$)____________. ADDITIONAL FUNDING IS BY SUBSTITUTION AS FOLLOWS:

PROJECT #	AMT. IN ORIG. PLAN	TITLE-ORIGINAL PROJECT

DIVISION SIGNATURES		HEADQUARTERS SIGNATURES		
DEPARTMENT HEAD	DATE	REVIEWED BY HEADQUARTERS MANUFACTURING		DATE
REVIEWED BY (DIV. CONTROLLER)	DATE	APPROVALS AS REQUIRED	EXECUTIVE VICE PRESIDENT	DATE
APPROVED BY (DIV. GEN. MGR.)	DATE		FOR CAPITAL EXPENDITURES COMMITTEE	DATE
	DATE		PRESIDENT	DATE
			BOARD OF DIRECTORS SECRETARY	DATE

DIVISION ______________________ APPROPRIATION NO. ______________________

1. EXPECTED BENEFITS FROM PROJECT:

	LATEST YEAR ACTUAL	FIRST YEAR OF NORMAL OPERATION YEAR	
		WITHOUT PROJECT	WITH PROJECT
ANNUAL SALES BILLED (000)	$ ________	$ ________	$ ________
PRODUCT COST (000)	________	________	________

RETURN ON INVESTMENT ________% WITH, ________% WITHOUT TERMINAL VALUE

2. DESCRIPTION OF PRESENT SITUATION WITH REASONS FOR PROPOSAL.

3. FACILITIES EXPENDITURES

BUILDINGS __________ SQ. FT. AT $ ______________ PER SQ. FT.

LAND __________ ACRES AT ______________ PER ACRE.

DURABLE EQUIPMENT $ ______________.

DISPOSITION OF OLD FACILITIES

APPROPRIATION DESCRIPTION

DIVISION ______________ APPROPRIATION NO. ______________

4. STATE PRINCIPAL FEASIBLE ALTERNATIVES

5. PERSONNEL EFFECTS.

6. WHAT ARE THE MAJOR AREAS OF UNCERTAINTY IN THE PROJECT

- [ ] INDUSTRIAL RELATIONS MANAGER
- [ ] ENGINEERING MANAGER
- [ ] MANUFACTURING MANAGER
- [ ] MARKETING MANAGER

______________ DIVISION MANAGER ______________ DATE

APPENDIX G

10% Compound Interest Factors

	Single Payment		Uniform Series				
n	Compound Amount Factor F/P	Present Worth Factor P/F	Sinking Fund Factor A/F	Capital Recovery Factor A/P	Compound Amount Factor F/A	Present Worth Factor P/A	n
1	1.1000	0.9091	1.000 00	1.100 00	1.000	0.909	1
2	1.2100	0.8264	0.476 19	0.576 19	2.100	1.736	2
3	1.3310	0.7513	0.302 11	0.402 11	3.310	2.487	3
4	1.4641	0.6830	0.215 47	0.315 47	4.641	3.170	4
5	1.6105	0.6209	0.163 80	0.263 80	6.105	3.791	5
6	1.7716	0.5645	0.129 61	0.229 61	7.716	4.355	6
7	1.9487	0.5132	0.105 41	0.205 41	9.487	4.868	7
8	2.1436	0.4665	0.087 44	0.187 44	11.436	5.335	8
9	2.3579	0.4241	0.073 64	0.173 64	13.579	5.759	9
10	2.5937	0.3855	0.062 75	0.162 75	15.937	6.144	10
11	2.8531	0.3505	0.053 96	0.153 96	18.531	6.495	11
12	3.1384	0.3186	0.046 76	0.146 76	21.384	6.814	12
13	3.4523	0.2897	0.040 78	0.140 78	24.523	7.103	13
14	3.7975	0.2633	0.035 75	0.135 75	27.975	7.367	14
15	4.1772	0.2394	0.031 47	0.131 47	31.772	7.606	15
16	4.5950	0.2176	0.027 82	0.127 82	35.950	7.824	16
17	5.0545	0.1978	0.024 66	0.124 66	40.545	8.022	17
18	5.5599	0.1799	0.021 93	0.121 93	45.599	8.201	18
19	6.1159	0.1635	0.019 55	0.119 55	51.159	8.365	19
20	6.7275	0.1486	0.017 46	0.117 46	57.275	8.514	20
21	7.4002	0.1351	0.015 62	0.115 62	64.002	8.649	21
22	8.1403	0.1228	0.014 01	0.114 01	71.403	8.772	22
23	8.9543	0.1117	0.012 57	0.112 57	79.543	8.883	23
24	9.8497	0.1015	0.011 30	0.111 30	88.497	8.985	24
25	10.8347	0.0923	0.010 17	0.110 17	98.347	9.077	25
26	11.9182	0.0839	0.009 16	0.109 16	109.182	9.161	26
27	13.1100	0.0763	0.008 26	0.108 26	121.100	9.237	27
28	14.4210	0.0693	0.007 45	0.107 45	134.210	9.307	28
29	15.8631	0.0630	0.006 73	0.106 73	148.631	9.370	29
30	17.4494	0.0573	0.006 08	0.106 08	164.494	9.427	30
31	19.1943	0.0521	0.005 50	0.105 50	181.943	9.479	31
32	21.1138	0.0474	0.004 97	0.104 97	201.138	9.526	32
33	23.2252	0.0431	0.004 50	0.104 50	222.252	9.569	33
34	25.5477	0.0391	0.004 07	0.104 07	245.477	9.609	34
35	28.1024	0.0356	0.003 69	0.103 69	271.024	9.644	35
40	45.2593	0.0221	0.002 26	0.102 26	442.593	9.779	40
45	72.8905	0.0137	0.001 39	0.101 39	718.905	9.863	45
50	117.3909	0.0085	0.000 86	0.100 86	1 163.909	9.915	50
55	189.0591	0.0053	0.000 53	0.100 53	1 880.591	9.947	55
60	304.4816	0.0033	0.000 33	0.100 33	3 034.816	9.967	60
65	490.3707	0.0020	0.000 20	0.100 20	4 893.707	9.980	65
70	789.7470	0.0013	0.000 13	0.100 13	7 887.470	9.987	70
75	1 271.8952	0.0008	0.000 08	0.100 08	12 708.954	9.992	75
80	2 048.4002	0.0005	0.000 05	0.100 05	20 474.002	9.995	80
85	3 298.9690	0.0003	0.000 03	0.100 03	32 979.690	9.997	85
90	5 313.0226	0.0002	0.000 02	0.100 02	53 120.226	9.998	90
95	8 556.6760	0.0001	0.000 01	0.100 01	85 556.760	9.999	95
100	13 780.6123	0.0001	0.000 01	0.100 01	137 796.123	9.999	100

APPENDIX H

PLANT MAINTENANCE RATING SHEET

Plant Atlanta Rated by Stone & Hunter Date 7-29-63

Final Grade- 83.4 Plant Rating B+

ITEM	Grade	Weight	Rating	Weight Factor	Points	Remarks
1 - BUILDINGS AND GROUNDS (EXTERIOR)						
ROOFING	95	10		12	114	
Flashings			10	3	30	
Parapet Walls			10	1	10	
Skylight			10	3	30	
Ductwork & Air Vents			10	1	10	
Roof Surface			10	3	30	
Coping Joints				-1-		
Cornice			4	1	4	Needs scraping & painting
Other:						
ELEVATIONS:	100	10		7	70	
Masonry			10	1	10	
Sills			10	1	10	
Columns			10	1	10	
Lintels and/or Arches			10	1	10	
Calking			10	1	10	
Joints			10	1	10	
Doors			10	1	10	
Other						
WINDOWS:	80	5		6	48	
Window Frame Paint			10	1	10	
Sash Ventilators			10	1	10	
Steel Lintels			10	1	10	
Panes			2	1	2	Many broken - need replacing
Hinges & Fasteners			10	1	10	
Other			6	1	6	Windows need cleaning
ACCESS AREAS:	87	5		31	270	
Walks			10	10	100	
Driveways			10	1	10	
Steps			10	10	100	
Ramps				-2-		
Parking Lots			6	10	60	Needs some repairs
Other:						

ITEM			Rating	Weight Factor	Points	Remarks
LANDSCAPING:	Grade 60	Weight 2		7	42	
Trees			6	1	6	Need trimming & clearing around
Shrubbery			6	3	18	Needs trimming around
Lawns			6	3	18	Cluttered with trash - some weeds
Other:	Rear of Building		6	3	18	Very cluttered & dirty
PLANT & GROUNDS GENERAL:	Grade 50	Weight 10		6	30	
Exterior Paint			6	3	18	Needed around cornice
Outside Hose Houses				~~3~~		
Gutters & Downspouts			4	3	12	Need repairs & paint
Other:						

II - BUILDING INTERIOR

ITEM			Rating	Weight Factor	Points	Remarks
STRUCTURAL STEEL:	Grade 100	Weight 2		2	20	
Columns			10	1	10	
Trusses			10	1	10	
INTERIOR WALLS:	Grade 100	Weight 10		2	20	
Walls			10	1	10	
Ceilings			10	1	10	
FLOORS:	Grade 75	Weight 8		12	90	
Aisles			10	3	30	
Work Areas			4	3	12	Trash & oil - cluttered
Drains			10	3	30	
Storage Areas			6	3	18	Disarranged - cluttered
DOORS:	Grade 100	Weight 1		6	60	
Hinges & Latches'			10	3	30	
Glass and Glazing			10	1	10	
Paint			10	1	10	
Caulking			10	1	10	
STAIRS:	Grade 100	Weight 1		30	300	
Hand Railings			10	10	100	
Treads & Landing			10	10	100	
Lighting			10	10	100	
WASH ROOMS:	Grade 85	Weight 10		40	340	
Plumbing			10	10	100	
Floors & Walls			10	10	100	
Fixtures			10	10	100	
Partitions			4	10	40	Some need repairs or replacing

APPENDIX I

INSPECTION CHECK LIST

Building No.__________ Occupancy__________ Plant______________

			Rating
1.	Outside Building	(a) Walls	______
		(b) Masonry	______
		(c) Sash (flashing)	______
		(d) Doors (flashing)	______
		(e) Roof (flashing)	______
		(f) Structural & Stairs	______
2.	Interior Building	(a) Walls	______
		(b) Masonry	______
		(c) Sash	______
		(d) Doors	______
		(e) Structural Steel	______
		(f) Elevators	______
		(g) Floors	______
		(h) Lighting	______
		(i) Floor Curbs & Sleeves	______
3.	Interior Utilities	(a) Building Heaters	______
		(b) Steam Piping (valves & traps)	______
		(c) Condensate Units	______
		(d) Ventilation	______
		(e) Conduit Runs	______
		(f) Elect. Control Rooms	______
		(g) Floor Drains	______
4.	Process Equipment	(a) Structural	______
		(b) Electrical of Equip.	______
		(c) Vessel	______
		(d) Vessel Insulation	______
		(e) Piping (inc.valves & hangers)	______
		(f) Piping Insulation	______
		(g) Pumps	______
		(h) Mech. Equipment	______
		(i) Instruments	______
		(j) Electric Motors	______

Rating Guide:

Top Condition	10
Good Servicable Condition	7
Below B.F.Goodrich Standards	4

Use intermediate grades for shading.

APPENDIX J

MILITARY CONSTRUCTION LINE ITEM DATA

1. Date	2. Fiscal Year	MILITARY CONSTRUCTION LINE ITEM DATA		3. Department	4. Installation
5. Proposed Authorization $		6. Prior Authorization P. L.	7. Category Code Number	8. Program Element Number	9. State/Country
10. Proposed Appropriation $		11. Budget Account Number	12. Line Item Number		13. Line Item Title

SECTION A - DESCRIPTION OF LINE ITEM

14. Type of Construction		18. Physical Characteristics of Primary Facility
a. Permanent		a. No. of Bldgs b. No. of Stores c. Length d. Width
b. Semi-Permanent		e. Design Capacity f. Gross Area
c. Temporary		g. Cooling Cap. Cost ($)
15. Type of Work		19. Description of Work To Be Done
a. New Facility		
b. Addition		
c. Alteration		
d. Conversion		
e. Other (Specify)		
16. Replacement		
17. Type of Design		
a. Standard Design		
b. Special Design		
c. Drawing No.		

SECTION B - COST ESTIMATES

20. Primary Facility	U/M	Quantity	Unit Cost	Cost ($000)
			$	$
a.		( )		( )
b.		( )		( )
c.		( )		( )
d.		( )		( )
21. Supporting Facilities				$
a.				( )
b.				( )
c.				( )
d.				( )
e.				( )
f.				( )
g.				( )
h.				( )
i.				( )
j.				( )
22. Total Line Item Cost				$

SECTION C - BASIS OF REQUIREMENT

23. Quantitative Data (U/M ______)		
a. Total Requirement		
b. Existing Substandard	( )	
c. Existing Adequate		
d. Funded, Not in Inventory		
e. Adequate Assets (c + d)		
	Authorized	Funded
f. Unfunded Prior Authorization		
g. Included in FY ____ Program		
h. Deficiency (a-e-f-g)		
24. Related Line Items		

25. Requirement For Line Item

APPENDIX K

SPECIAL PROJECTS REQUEST
(SIDE 1)

DEPARTMENT OF THE NAVY
SPECIAL PROJECTS REQUEST
NAVFAC 9-11014/41
Supersedes NAVDOCKS 2950

SHEET 1 OF 2

1. ACTIVITY SNDL NO.: 1452-342 | ACTIVITY NAME AND LOCATION: Naval Station ANYWHERE | DATE SUBMITTED: 7 Jun 1965

2. PROJECT NO.: R-3-65 | TITLE: Repair Refrigeration Plant Bldg. 2

3. TYPE
a. [X] MAINT./REPAIR b. [ ] MINOR CONSTRUCTION/ ALTERATION c. [ ] AIR CONDITIONING d. [ ] EQUIPMENT INSTALLATION

4. DESCRIPTION AND FUNCTION OF FACILITY
Bldg. 2 contains half the station's frozen storage space which is essential in operation of messing facilities

a. PROPERTY RECORD CARD NO. 2-00015
b. NAVY CATEGORY CODE 43210
c. BLDG. OR STRUCTURE NO. Bldg. 2

5. WHAT IS THE EFFECT OF THIS PROJECT ON THE MISSION OF THE ACTIVITY?
Facility is necessary to maintain reliable stocking levels for operation of station messing facilities - 7 mo. stock considered minimum level - presently able to maintain 4 mo.

6. THE REQUIREMENT FOR THE FACILITY IS BASED ON:
a. [ ] A CHANGE IN MISSION b. [X] FULL-TIME CONTINUING NEED c. [ ] 3 TO 5 YEAR NEED d. [ ] LESS THAN 3 YEARS' NEED e. [ ] CURRENTLY REQUIRED LESS THAN 50% OF TIME f. [ ] RESERVED FOR FUTURE REQUIREMENTS

7a. EST. FUNDED COST	b. EST. PROJECT COST	c. EST. PLANNING COST	d. TOTAL FUNDS REQUESTED	e. EST. FACIL. REPL. COST
$ 85,000	$ 87,000	$ 5,1000	$ 90,100	$ 150,000

8. DATE FACILITY CONSTRUCTED: 1942

9. IS FACILITY ON AN APPROVED BASIC FACILITY REQUIREMENTS LIST? If "NO," how was need determined?
[X] YES [ ] NO

10. IS PROJECT LISTED ON ANNUAL INSPECTION SUMMARY? If answer is "NO," and AIS is applicable, explain exclusion.
[X] YES [ ] NO [ ] N.A

11. 3-LINE DESCRIPTION OF CONDITION TO BE CORRECTED, OR PROBLEM TO BE SOLVED WITH PROPOSED SOLUTION. Attach additional description if necessary. ONE PAGE ONLY.
Insulation and equipment have deteriorated so that it is impossible to maintain required temperatures. Project will replace refrigeration system serving frozen food rooms, floor insulation and two refrigerator doors.

12. WHY IS THE PROPOSED SOLUTION BEST — AND WHAT ALTERNATIVES WERE CONSIDERED?
Only alternative is new construction - repair is more economical.

13. WERE ANY NON-NAVY EXPERTS INVITED TO REVIEW THIS PROBLEM AND THIS SOLUTION? Explain effect on solution.
a. [ ] YES b. [X] NO

14. HAS EFD DESIGN DIVISION REVIEWED SOLUTION? a. [X] YES b. [ ] NO

15. CAN ANOTHER FACILITY BE ECONOMICALLY ADAPTED FOR THIS FUNCTION? a. [ ] YES b. [X] NO

*16. CAN PROJECTS BE FUNDED IN INCREMENTS? How?
a. [ ] YES b. [X] NO

*17. THIS PROJECT IS THE RESULT OF
a. [ ] INADEQUATE HOUSING b. [X] FACILITY AGE c. [ ] DEFICIENT CONSTR d. [ ] DEFICIENT DESIGN e. [ ] OTHER ____

*18. HAS THIS SPECIFIC PROBLEM BEEN COMPLETED PREVIOUSLY?
a. [ ] YES b. [X] NO When?
HOW LONG WILL PROPOSED CORRECTIVE ACTION LAST? 15 YEARS

19. ARE COMPONENTS BEING INCREASED IN SIZE OR CAPACITY? Explain the difference including cost.
a. [ ] YES b. [X] NO

SPECIAL PROJECTS REQUEST
(SIDE 2)

20. ARE MATERIALS PROPOSED FOR USE THE SAME AS THOSE EXISTING? If "NO," explain the difference, including cost.

a. [X] YES b. [ ] NO

21. PROJECT IS PLANNED TO BE ACCOMPLISHED BY

a. [ ] STATION LABOR b. [X] CONTRACT

22. HAS A PROJECT EVER BEEN SUBMITTED FOR THE REPLACEMENT OF THIS OR SIMILAR FACILITIES? Check and explain if "YES."

a. [ ] YES b. [X] NO When?

23. ANTICIPATED SAVINGS IF PROJECT IS DONE THIS YEAR AS COMPARED TO A DEFERRAL OF ONE YEAR.

PROBABLE INCREASE IN PROJECT COST FOR ANY JUSTIFIABLE REASON	REDUCTION IN CURRENT MAINT. COST	REDUCTION IN CURRENT OPERATIONS COST
$ None	$ 2,500	$ 1,000

JUSTIFY ANY SAVINGS INDICATED

Job orders reveal maint. costs for repairing worn out equipment averages $2,500 annually. Overtime costs for manual operation average $1,000 annually.

WHAT IS PAY BACK PERIOD OF PROJECT? (In years) 15

WILL ACCOMPLISHMENT GENERATE REQUIREMENTS FOR ADDITIONAL M&O FUNDS OR PERSONNEL? a. [X] NO b. [ ] YES Est. Ann.

24. WHAT WOULD BE THE EFFECT OF DEFERRING THE PROJECT ONE YEAR?

Sufficient food could not be stored to operate messes in summer months.

*25. IF THE PROJECT IS NOT ACCOMPLISHED NOW, IN HOW MANY YEARS WILL THERE BE SERIOUS DAMAGE TO THE FACILITY AND/OR ITS CONTENTS OR IMPAIRMENT TO ESSENTIAL OPERATIONS? Explain, include loss value to facility and/or contents.

YEARS BEFORE SERIOUS DAMAGE OCCURS 1 . Equipment will be completely unreliable in one year.

*26. HAS THE REDUCED UTILIZATION OF THIS SPECIFIC FACILITY AFFECTED A LARGE FACILITY SYSTEM OPERATION? Explain.

a. [X] YES b. [ ] NO BY HOW MUCH? 25 %. Cold storage capacity station wide has been reduced 25%.

27. ARE THERE ANY OTHER FACTORS INVOLVED? Check and explain.

a. [ ] MORALE b. [X] HEALTH c. [ ] PUBLIC RELATIONS d. [ ] SAFETY e. [ ] FIRE PROTECTION f. [ ] SECURITY g. [ ] OTHER

Provisions have spoiled which could result in serious health hazard

28. CERTIFICATION BY RESPONSIBLE OFFICER AT ACTIVITY: I am personally cognizant of the need for, the essentiality of, and the proposed method of accomplishment of this project and certify that the above information is correct, and that this project meets all criteria specified in OPNAVINST P-11010.20

DATE	TYPED NAME OF OFFICER AND POSITION	SIGNATURE
7 Jun 1965	LCDR G. S. High (CEC) USN CODE 80	

FEO EVALUATION BY DIRECTOR, DEPUTY, OR MAINTENANCE DIVISION SUPERVISOR: I hereby certify that this project has been thoroughly evaluated, that it is an essential project, and that it is both economically and technically sound. A rating factor is hereby assigned.

29. VALID FOR RATING FACTOR

a. [X] VASP
b. [ ] PROJECTED MAINT.
c. [ ] NOT VALID
d. [ ] OTHER

30. FED Rating

**The product of (4) x (5) must NOT be greater than 2.5.
***If safety is evaluated in (4), do not duplicate safety in the rating.

(1)		(2)		(3)		(4**)		(5**)		(6***)		
1.0	x	1.0	x	1.0	x	1.6	x	1.4	x	~~1.1~~	x 100 =	238

31. DATE	TYPED EVALUATOR'S NAME AND POSITION	SIGNATURE
26 Jun 1965	CDR J. Jim (CEC) USN Code 60	

ENCLS:

a. [X] ENGINEERING EST. (NAVDOCKS 2417) b. [X] LOCATION PLAN(S) c. [X] DRAWINGS d. [X] PHOTOGRAPHS

NAVFAC 9-11014/64
(REV. 5-65) SHEET 2 of 2

*NOT applicable to Minor Construction, Alterations, or Equipment Installation

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